Range Management in the Central and Southern Rocky Mountains:

A Summary of the Status of Our Knowledge by Range Ecosystems

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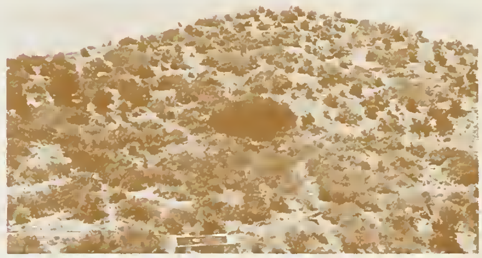
USDA Forest Service
Research Paper RM-154
Rocky Mountain Forest and
Range Experiment Station
Forest Service
U.S. Department of Agriculture
Fort Collins, Colorado 80521
October 1975






Abstract

Summarizes a series of comprehensive reports on range management in the seven recognized ecosystems: Semidesert grass-shrub, southwestern chaparral, pinyon-juniper, central Rockies ponderosa pine-bunchgrass, Arizona ponderosa pine-bunchgrass, mountain grassland, and alpine. Includes what is known, what can be recommended, and what additional information is needed for each ecosystem.

Keywords: Range ecosystems, semidesert grass-shrub, southwestern chaparral, pinyon-juniper, central Rockies ponderosa pine-bunchgrass, Arizona ponderosa pine-bunchgrass, mountain grassland, alpine.

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PREFACE

Seven comprehensive, in-depth reports drawn from the current literature on range management have been prepared by range scientists of the Rocky Mountain Forest and Range Experiment Station for the important range types in the central and southern Rocky Mountains. These reports have been condensed and arranged in a common format here to provide a summary of information that is available to the range managers, and is especially applicable for range management in the seven recognized ecosystems. Only those literature citations not included in the full-length papers are mentioned in this summary.

We recognize there also exists a considerable body of valuable range management knowledge that has been accumulated through experience and familiarity with specific range situations. This knowledge permits a higher degree of sophistication of range management in local areas, but such information is not generally available in the published literature. Individual reports are as follows:

Semidesert Grass-Shrub Ecosystem—

"Ecology and management of southwestern semidesert grass-shrub ranges: The status of our knowledge," by S. Clark Martin (RM-156).

Southwest Chaparral Ecosystem—

"Range management in the chaparral type and its ecological basis: The status of our knowledge," by Dwight R. Cable (RM-155).

Pinyon-Juniper Woodland Ecosystem—

"Characteristics and management of southwestern pinyon-juniper ranges: The status of our knowledge," by H. W. Springfield (RM-160).

Central Rockies Ponderosa Pine-Bunchgrass Ecosystem—

"Grazing management of ponderosa pine-bunchgrass ranges of the central Rocky Mountains: The status of our knowledge," by Pat O. Currie (RM-159).

Arizona Ponderosa Pine-Bunchgrass Ecosystem—

"Range management and its ecological basis in the ponderosa pine type of Arizona: The status of our knowledge," by Warren P. Clary (RM-158).

Mountain Grassland Ecosystem—

"Management of mountain grassland: The status of our knowledge," by George T. Turner (RM-161).

Alpine Ecosystem—

"Alpine range management in the western United States—principles, practices, and problems: The status of our knowledge," by John F. Thilenius (RM-157).

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RANGE MANAGEMENT IN THE CENTRAL AND SOUTHERN ROCKY MOUNTAINS:
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INTRODUCTION

In addition to the intrinsic characteristics of the site, four factors affect the management of any range area—economics, social pressures, multi-purpose demands, and the availability and acceptance of new knowledge. Traditionally, the term "range" has been associated with cattle and sheep grazing, which became prominent in the western United States in the last quarter of the 19th century. More recently, rangelands have become increasingly important for additional values, although domestic livestock grazing continues to be a significant element.

Through more than 70 years of research and management experience, sound techniques and informational guidelines have been developed which provide the basis for range management under domestic livestock use. Pertinent information can be found on the ecology and management of most major range and forest-range ecosystems. However, today's land manager must direct his effort within multiple use constraints; the view that rangelands are primarily the domain of the livestock industry is no longer tenable.

Rangelands are commonly recognized as uncultivated areas that support herbaceous or shrubby vegetation; they may or may not have a tree overstory. The rangeland complex encompasses the vegetation, soil, atmosphere, water, and animal life. Although most ranges are characterized by native plants, extensive areas have been seeded to exotic species to increase forage production and improve range condition.

In general, ranges have relatively low biological productivity (Clawson 1972),[2] and hence are sometimes referred to as economic residuals after more productive sites were converted to higher economic uses such as improved pastures and croplands. While limited plant growth is typical of most ranges, rough topography, remoteness, shallow soil, low rainfall, and severe temperatures are also frequently implicit in the concept of rangelands (Thomas and Ronningen 1965). Additionally, socioeconomic factors further complicate the manager's task.

Efforts to improve rangeland productivity must often be restricted because of economic considerations. Only relatively inexpensive means can be employed, and these must be amortized over long periods. Likewise, economic constraints limit the research that can be justified, particularly in grazing experiments where large areas of land are needed to provide the necessary replications (Thomas and Ronningen 1965).

From the national viewpoint, livestock production on rangelands is but a modest part of today's total commercial agriculture (Blaisdell et al. 1970). Nevertheless, grazing of rangelands by domestic or wild herbivores converts a product (forage) that otherwise would not be utilized. Furthermore, of the energy garnered from the sun, about 10,000 calories of fossil fuel per person per day are expended to harvest about 3,000 calories stored in foods grown on cultivated lands (Thomas 1971). In contrast, the fossil fuel requirements for livestock production on rangelands is very small. Thus, critics who contend that we cannot afford to convert plant products into animal products must recognize that ruminant animals subsist in large part upon matter which, if not utilized, would lower the earth's total food-producing potential (Van Horn et al. 1972).

However, to consider rangelands only in the context of livestock production is simplistic. Society has an interest in these lands from a multiple use standpoint, and in some areas social considerations outweigh direct income alternatives (Thomas and Ronningen 1965). Nevertheless, the economic fabric and

[2] *Only those literature citations not included in the full-length papers are mentioned in this summary.*

social well-being of many rural areas are heavily dependent on and oriented toward rangeland livestock operations.

Moreover, in our present society, absentee owners, land speculators, miners, sportsmen, and other recreationists are claiming an increasing voice in what happens on the land. Recent public concerns about esthetics, habitat destruction, or the balance of nature, have influenced policies of public land administration and the use of private lands as well. Added to these concerns is the loss of land to other uses such as surface mining and residential subdivisions.

In many cases, however, herbage and browse on rangeland can contribute far more feed for livestock and wildlife than it now provides. Increased understanding of the interrelationships among the plants, animals, and their environment is of fundamental significance if we are to realize the full potential of the nation's range resource. It has been optimistically predicted that future research could lead to techniques for doubling or even tripling the productivity of rangelands (Thomas and Ronningen 1965). For example, beef production has been more than doubled on seeded-native range combinations at the Eastern Colorado Range Research Center (Denham 1973).

One of two major purposes of this paper is to provide a compendium of information for the land manager faced with managing the range resource of the central and southern Rocky Mountains. The second is to identify gaps in our knowledge which handicap prudent usage of the range resource.

The major biotic and abiotic attributes of seven range ecosystems are highlighted, and management practices that have proved feasible are described. Where a lack of knowledge forestalls sound resource management, the needed research has been identified by priority.

The seven range (including forest-range) ecosystems described encompass over 150 million acres in Arizona, New Mexico, west Texas, Colorado, Wyoming, and the Black Hills. They comprise about 12 percent of the pasture and native grazing lands of the United States. Recognized are semidesert grass-shrub, chaparral, pinyon-juniper, central Rockies ponderosa pine-bunchgrass, Arizona ponderosa pine-bunchgrass, mountain grassland associated with subalpine forests, and alpine grasslands. Three additional ecosystems contribute substantially to the total range acreage of the entire region: the shortgrass plains and sandhills, sagebrush-grass, and southern desert shrub.

The pattern of land ownership, type of ranching operation, and the demands on the range resources differ markedly from the lower elevations to the high mountains. Much of the land area is in federal ownership, railroads hold title to millions of acres, and additional vast acreages are in State lands. Biological features are characterized by wide diversity in plants and wildlife. Extremely wide differences in elevation, climate, geology, and other physical characteristics add to the complexity of management.

Dispersed in each of the seven ecosystems are plant communities associated with high moisture regimes. The riparian and phreatophyte vegetation found along watercourses and around the perimeter of natural or manmade lakes and on flood plains is often the most productive of any ecosystem. Unfortunately, this vegetation is also often the most severely overused and depleted. Concentrations of livestock coupled with direct or indirect human activities have materially altered their inherent productive capability and created many downstream problems. Overgrazing has resulted in depletion of the vegetation and cutting of the stream channel. Lowering of the water table has converted plant communities to species that require less water for survival, but also are less productive. Diversion of water from the streams for irrigation use, coupled with the high recreation value of water-related sites, have compounded the problems.

Flood plains have been converted to farmlands or improved pasture thereby altering their ecological niche and possibly increasing their economic worth. However, other intangible values that depend on the natural state of these ecosystems may be irretrievably lost. For example, their significance to wildlife including fish, recreation, esthetics, and preservation of natural areas must be recognized in multiple use management.

The management of riparian and phreatophyte ecosystems is inseparable from the management of adjacent ecosystems that have been more fully treated here, although special consideration is required to preserve or improve them.

General Characteristics

The Southwestern semidesert grass-shrub ecosystem occurs in a discontinuous belt 50 to 100 miles wide as arid grasslands intermingled with shrubby or low trees on the broad flat valleys and lower mountain slopes, generally at elevations between 3,000 and 5,000 feet. It occupies nearly 60 million acres, largely in western Texas and the southern parts of Arizona and New Mexico, where it is in close contact with the southern desert shrub type and the shortgrass plains (fig. 1).

The major vegetation communities include mixed grama grasslands, flood plains of tobosa [3] or sacaton, and mesquite-grasslands (fig. 1). Additionally, several shrub-dominated communities with affinity to the lower desert shrub ecosystem may be found.

[3] *Common and scientific names of specific plants mentioned are listed at the end of the individual full-length papers.*

The entire semidesert region has significantly changed in the last 100 years. Grazing by domestic animals has reduced the abundance of preferred forage species, which have been replaced by plants that are less palatable to livestock. For example, shrubs, unpalatable forbs, and annual or short-lived perennial grasses are characteristic of ranges that have suffered past abuse. Invasion by these species usually have been accompanied by decreased forage production and increased soil erosion. They are indicators of mismanagement and disruption of the ecological balance that had previously kept them in check.

The climate is characterized by mild winters and hot summers. Annual precipitation may reach 20 inches, but at least half of the area receives little more than 10 inches per year. There are two distinct rainy periods, one in summer and one in winter; the percentage of the annual precipitation received in the summer increases from west to east.

Figure 1.—Semidesert grass-shrub types: **A,** Mixed grama grassland interspersed with mesquite trees; **B,** Dense stand of tobosa on a swale with heavy clay soils.

Forage production depends on summer rains, which usually begin around mid-July in the central portion of the type. These rains produce about 90 percent of the forage, which consists mainly of perennial grasses; certain browse species and annual grasses are sometimes important.

The seasonal distribution of precipitation significantly affects plant growth, and must be recognized in grazing management. Although perennial grasses produce only a small amount of herbage in March and April, this growth is often critical to the subsequent production of forage the following summer. Culms that make the bulk of their growth in response to the summer rains originate during the preceding spring or fall. Two consecutive summers with ample, well-distributed rainfall can be expected to produce high forage yields because of this sequence of culm initiation and growth proliferation. However, wide fluctuations in precipitation are common, with consequent great year-to-year variations in forage production.

Semidesert grass-shrub ranges are grazed mainly by cattle. The nutritive quality of most forage species is adequate for them during the growing period, but perennial grasses are usually deficient in protein, phosphorus, and vitamin A by midwinter. On ranges where there is a mixture of grasses and palatable shrubs, cattle can usually select a diet that is adequate in protein in all but the coldest part of the year.

Most semidesert ranches are cow-calf operations. Calves are born in early spring and sold when they are weaned in late fall. This schedule coincides with the growth of forage. Calves are large enough to take their mother's increased milk production during the flush of growth, and usually are as heavy by late fall as they will be 6 to 8 months later after being weaned and wintered on the range.

Ranges better suited to yearlings or steers than to cows and calves include rough or rocky areas that are better used by lighter, more active animals, and remote or brushy ranges where losses of young calves to predators might otherwise be excessive.

Semidesert ranges support a variety of wildlife. Increased shrub cover on some semidesert ranges has improved the habitat for deer at the expense of forage production for cattle. In some areas it has been more profitable to manage a range to produce a mixture of wildlife and livestock, where substantial income can be obtained from the sale of hunting privileges. Other recreational activities in the semidesert range ecosystem are becoming popular among urban residents of the region or winter tourists.

Flexible stocking is often recommended for semidesert ranges because forage production varies greatly from year to year. For cow-calf operations, the breeding herd probably should be kept at less than 70 percent of the average capacity for the range; extra forage in good years could be utilized by carrying over extra yearlings. In years of low production, the normal complement of yearlings would be sold and only the breeding herd would be kept. A serious shortcoming of this plan is that each year's forage crop is not known until the growing season is over. If extra calves are kept on the range following a good summer forage crop, they should be sold the following spring. If the extra animals are not sold in May or June, the range may be overstocked during the next growing season (July-September). In most years holding calves only until spring is not profitable because weaner calves gain little in weight or value from November 1 to May 31.

If calves are held over until the fall of their second year they normally will have gained 200 or more pounds and usually be worth about one-third more than they were as calves. A recent evaluation of various stocking plans for southern Arizona range showed that net sales per animal unit of stocking were lower for cow-yearlings than for cow-calf operations. This study showed that net sales were highest when the breeding was maximized, and that constant stocking at 90 percent of average carrying capacity was much less risky than flexible stocking and produced almost as much income.

Semidesert ranges are better suited for producing calves than for putting weight on yearlings because semidesert forage produces rapid weight gains only during the summer growing season. Holdover yearlings mark time for 8 or 9 months (November-June), then make all of their gain for the year during a period of 3 or 4 months. Income per animal unit of average stocking usually is less for cow-yearling production than for cow-calf production. Exceptions do occur, however, as when feed costs are so high that feeders pay more per pound for a 650-pound yearling than for a 400-pound calf. Continued high feed prices could shift the advantage from cow-calf to cow-yearling production. This would increase the relative contribution of range forage to finished beef, but would reduce the number of animals produced and decrease total beef production for the region.

Range Management Prescriptions

Stocking and Forage Use

As a basic premise, management of semidesert grass-shrub ranges should be focused on maintaining or developing productive stands of perennial grasses, which are the most reliable and productive component of the forage resource. Traditionally, these ranges have been grazed yearlong. Annual stocking has varied widely because of large fluctuations in forage production. As a rule of thumb, however, the number of cattle grazed should utilize about 40 per-

Table 1.--Estimated average yearlong stocking rate, by condition class, for semidesert grass-shrub range

Elevation (Feet)	Precipitation	Range condition class					
		Very poor[1]		Poor and fair		Good and excellent	
	Inches	*Animals/ square mile*	*Acres/ animal*	*Animals/ square mile*	*Acres/ animal*	*Animals/ square mile*	*Acres/ animal*
High (4,000-5,000)	16+	<12	>50	15-18	35- 45	18-25	25- 35
Intermediate (3,300-4,000)	12-16	<6	>100	6-12	50-100	12-16	40- 50
Low (Less than 3,300)	12	<4	>160	4- 6	100-160	6-10	60-100

[1] < signifies less than; > signifies more than.

cent of the perennial grass production in an "average" year. This guideline applies to land that is inherently suitable[4] for livestock grazing and is in fair or better range condition. Average yearlong stocking rates developed on the Santa Rita Experimental Range apply for most semidesert ranges suitable for cattle grazing (table 1).

Grazing Systems

Research and experience have shown that continuous yearlong grazing results in overuse of the forage and deterioration of the forage stand in areas of livestock concentration, while forage in remote parts of the range is largely unused. Still, if average utilization of the most important perennial grasses over the entire range unit does not exceed 40 percent at the end of the grazing year, immediately before the flush of new growth from summer rains begin, continuous yearlong grazing is less destructive than some of the alternatives that have been tried. Rotation systems may fail because the rest periods are too short, too infrequent, or at the wrong season to allow forage plants to recover from grazing. The early spring period is especially critical for forage plants because cattle and wildlife, which are particularly hungry for nutritious green herbage at that time, regraze the fresh new growth on plants that have been previously grazed. Rotation schedules that intensify spring regrazing can weaken the favorite forage plants so severely that they are not able to recover during the ungrazed periods. Systems that have been successful rest each range unit from one-half to two-thirds of the time, and reduce spring regrazing by moving the herd to an ungrazed crop of old herbage for the spring period.

Average use of key forage plants under complex grazing systems should be about 40 percent—the same as for continuous grazing. If adequate rest periods are provided, however, the occasional heavy use in years of low forage production does not do serious damage. Animal weight gains often are slightly less for complex systems than for continuous grazing, probably because the animals are at times forced to graze more mature forage and because the additional moves disturb the animals.

The rest rotation system advocated by Hormay provides rest periods to meet specific requirements of the forage species: to recover vigor, promote seed production, and enhance new plant establishment. The system usually involves three or four pastures of about equal capacity. This system will benefit many semidesert ranges if the grazing schedules are properly meshed with forage growth periods.

The high-intensity/low-frequency system of grazing, which was introduced in Africa and is currently being tested in Texas, requires movement of all cattle from a pasture when the desired degree of forage use is obtained, regardless of season or forage phenology. The period of intervening rest is contingent upon the number of pastures and the level of stocking. Results to date indicate remarkable improvement in a few years where relatively long rest periods have alternated with short grazing periods.

On semidesert ranges in Arizona, rest for each range unit 2 years out of 3 during the period March through October holds promise for improving the range (table 2). Advantages reported under these systems include reduced labor costs because the cattle are in one pasture, and possibilities for range improvements such as brush control or seeding without fencing the treated area.

Unfortunately, climatic events can override the desirable effects of any grazing system in the semi-

[4] *Suitable range is defined as range that can be grazed on a sustained-yield basis in harmony with other resource uses and values under reasonable management. Stocking rates that are cited apply to ranges classified as suitable.*

Table 2.--A grazing system being pilot tested on the Santa Rita Experimental Range that provides 12 months of rest immediately before each period of spring-summer (March-October) grazing

Season	Pasture 1	Pasture 2	Pasture 3
First:			
Spring-summer	Graze	Rest	Rest
Winter	Rest	Rest	Graze
Second:			
Spring-summer	Rest	Graze	Rest
Winter	Graze	Rest	Rest
Third:			
Spring-summer	Rest	Rest	Graze
Winter	Rest	Graze	Rest

desert Southwest. Severe and prolonged drought will reduce perennial grass stands whether or not they are grazed. Under these circumstances the range manager must reduce stocking to prevent undue range deterioration and animal losses. Range will recover more rapidly with favorable rainfall where the forage plants have not been overgrazed prior to the drought.

Range Improvement Practices

Practices aimed at increasing range productivity have been developed for semidesert grass-shrub ranges. All too often, however, the incentive to improve these ranges has been lacking because of their inherent relatively low productivity and high risk of failure unless proven seeding techniques are carefully followed. Range seeding, brush control, water spreading, rodent and rabbit control, and fertilization have been tried.

Seeding of semidesert grass-shrub rangelands may be needed and justified if satisfactory range condition cannot be restored within a reasonable time through grazing management or control of undesirable plants. Extreme scarcity of desirable plants is one of the most obvious indicators of the need to reseed. Suitability of the site for seeding, need for additional forage or ground cover, ability to protect and manage the seeded area, and costs and returns from seeding must be considered.

Reliable seeding methods are known for the better semidesert grass-shrub sites. Seeding generally should be done just prior to the summer rains. Fairly level areas with relatively deep, fertile, medium-textured soils will have the best chances for success. Seeding is hazardous where annual rainfall is less than 11 inches. Where annual rainfall is 11 to 14 inches, Lehmann lovegrass can be generally recommended for seeding depleted range sites. Sites above 4,000 feet that receive more than 14 inches of annual rainfall can be seeded to Boer lovegrass. On swale or bottomland sites a wider choice of species is available.

Site preparation is essential before seeding. If undesirable competing vegetation is abundant, it should be controlled before seeding. Measures to conserve moisture such as pitting with an eccentric disk, contour furrowing, and ripping have increased chances of seeding success. Broad, and shallow pits retain their value longer and produce more herbage. Larger seeds are best planted with a drill; a cultipacker-seeder should be used for planting small seeds.

In general, newly seeded stands should not be grazed until seed has been produced. By this time the root system has developed sufficiently so it will not be pulled out of the ground by grazing animals. Once seeded grasses are established, proper management of the stand is required.

The presence of one or more species of noxious plants decreases grass production and often accelerates sheet and gully erosion. Furthermore, the presence of overstory plants increases the cost of handling range livestock, a factor that is becoming increasingly important to the range livestock operator.

Mesquite is one of the most widespread overstory plants on Southwestern rangelands. It, together with woody species such as creosotebush, cacti, burroweed, and other noxious shrubs, has lowered materially the semidesert range forage productivity.

Control methods depend upon growth characteristics of the species, density, size, and whether seeding is required to achieve the desired range improvement. The method employed will also depend upon the site characteristics and management objectives for each area. Methods include hand grubbing, individual stem or stump treatments with diesel oil and/or herbicides, application of granular herbicides to the soil around trees, aerial applications of herbicides, individual tree dozing, cabling, roller chopping, root plowing, and prescribed burning.

For scattered mesquite, hand grubbing is effective for plants up to 1 inch in diameter. It is a high-cost labor method that will not pay immediate returns on the investment, however, because removal of small plants does not increase forage production perceptibly; it must be justified as preventive maintenance.

Immediate and often dramatic increases in forage production can be obtained by controlling moderate or dense stands of mesquite with herbicides or mechanical methods if there is a remnant of perennial grass. Treatments can be applied to individual trees or broad scale to a large area. Individual trees or groups of trees may be left for shade, esthetics, or wildlife habitat; however, remaining trees are centers for reinvasion.

Root plowing destroys or seriously disturbs all vegetation including perennial grasses, so reseeding at the time of plowing is usually mandatory for prompt reestablishment of a forage stand.

Fire was an important element in maintaining semidesert grasslands prior to white settlement. Although mesquites less than ½ inch in stem diameter are often killed, prescribed burning can rarely be used to control moderate to dense stands of large mesquite because there is seldom enough herbaceous fuel to carry a fire of sufficient intensity. Moreover, many perennial grass species may be severely damaged by fire and often are slow to recover.

The various control techniques mentioned above also can be used with some degree of success for other undesirable low-growing trees or shrubs.

Improving Livestock Distribution

Management practices applicable on most range ecosystems for improving livestock distribution include: stock water development, hauling of water, fencing for better livestock control, location and periodic movement of salt grounds, range riding, and construction of trails and driveways.

Livestock water can be developed by the use of windmills, deep-pit charcos, sand tanks, temporary ponds, horizontal wells, and paved runoff catchment areas with closed storage tanks. With flexible plastic pipe, water can be distributed from a central source to widely separated range units at a relatively low cost. Permanent waters should not be further than 4 to 5 miles apart in flat or undulating country, 3 miles in rolling country, and from 1 to 2 miles on rough ranges.

Fencing a range into suitably sized areas should be an integral part of the management plan of any range operation. Fence locations must be based on availability of water, topography and vegetation, class of livestock, and kind of grazing system used.

Salt placed away from water usually improves the distribution of cattle and increases forage use in lightly grazed areas. In rough terrain, salt grounds probably should not be over ½ to 1 mile apart, and location should be changed whenever the desirable forage plants show damage from trampling and grazing.

Riding to obtain better distribution of cattle is relatively expensive, but it is a positive method of dispersing the animals to achieve more uniform grazing.

As a companion to these management techniques, recommended livestock husbandry practices include gentle handling of animals, use of modern conveniences such as holding traps, corrals, squeeze and separating chutes, and branding tables. These greatly reduce animal losses and injuries as well as labor costs.

Additional Needed Guidelines

Sound informational guidelines have been developed for managing livestock production operations on semidesert grass-shrub ranges. The resource manager needs additional information, however, that will enable him to meet today's complex problems which encompass more than just livestock production.

In the semidesert Southwest, recent population increases of permanent and transient residents in large metropolitan centers and numerous scattered suburban communities have created a set of new challenges for the range manager. The economic advantages and the social demands which stem from this influx of people dictate that we now must develop knowledge that will enable the resource manager to integrate the various recreation and esthetic amenities which people expect to enjoy with the conventional and historical uses of the region.

Of particular importance is a provision for enjoyment of wildlife, both for its consumptive and nonconsumptive values. Wildlife habitat improvement is prerequisite to achieving this goal. Various grazing systems and range improvement practices must accommodate these new demands while at the same time, hopefully, increasing livestock production and improving the range. It will be the responsibility of the scientists representing several disciplines to determine acceptable tradeoffs for managing the semidesert grass-shrub ecosystem within a multiple use framework instead of for a single product.

Although we have a general understanding of the habitat types represented within the semidesert grass-shrub ecosystem, improved classification standards are needed as an adjunct to intensified management. With proper classification of the habitat types and knowledge of their potential, the manager will have available the basic building blocks.

If multiple use management is to be realized, we must develop improved methods of vegetation manipulation. Removal of mesquite or other taller vegetation in eye-pleasing and wildlife-benefiting patterns can increase the diversity of the ecosystem.

Since fire at one time was a component of prewhite settlement, better knowledge of its effects and how it can be used in the current management scheme could be important for the manager.

More intensive testing of forage and browse species, including methodologies necessary for their establishment, would be useful for rapid improvement of disturbed or deteriorated sites.

SOUTHWEST CHAPARRAL ECOSYSTEM

General Characteristics

Chaparral is a low and often dense scrub vegetation. In Arizona, the chaparral ecosystem occupies a relatively narrow band of broken, rough terrain below the Mogollon Rim. It extends through the central part of the State from northwest to southeast, at elevations mostly between 3,000 and 6,000 feet. Precipitation is concentrated in two distinct periods, summer and winter. In this, the Arizona chaparral ecosystem differs markedly from other chaparral communities of the world, whose climates are characterized by wet, mild winters and hot, dry summers. Annual precipitation averages from 15 to 25 inches; approximately half is received in the summer. Average snowfall within the type varies from 4 to 25 inches per year.

Settlement of the chaparral region lagged some years behind other range areas in the Southwest because of the rough topography. Cattle were brought in by settlers in the last quarter of the 19th century, and peak stocking was reached about 1900. Drought and overgrazing soon resulted in loss of carrying capacity and reduced livestock numbers. Originally the shrub cover was relatively open with excellent stands of interspersed grasses, but by the early 1900's the chaparral had taken on much of the dense shrub character evident today.

The present chaparral ecosystem is a remnant of a semiarid woodland and thorn scrub vegetation which once (pre-Pleistocene) extended from California to Oklahoma. With climatic changes and mountain building, the vegetation became separated into California and Southwestern segments. The chaparral type in Arizona is about all that remains of the Southwestern segment. According to Clements it represents a climax formation, but it is a climatic climax that is often subjected to huge conflagrations which temporarily destroy the shrub cover. Others have theorized that it is a fire climax which often presented a presettlement aspect of open grassland mixed with low shrubs that were suppressed by frequent fires and vigorous grasses. In either case, because the major shrub components either sprout prolifically after a fire or produce abundant seeds which are scarified by fire, chaparral stands tend to recover rapidly after burning with only minor changes in shrub cover.

The distribution of chaparral and adjacent intermingled vegetation types is complex. Chaparral is associated with pinyon-juniper, ponderosa pine, and desert ecosystems, depending upon combinations of environmental features and the ecological amplitudes of the characteristic species. Shrub crown cover is greater at the higher elevations, and decreases to about 25 percent at the lower elevations where it becomes transitional with the semidesert grass-shrub or desert shrub ecosystems.

Chaparral is found on soils developed from sedimentary, igneous, and metamorphic parent rocks. Sedimentary rocks predominate in the central portion of the type, however, and granitic rocks over most of the remainder. Soils are mostly sandy in texture, relatively shallow, and low in fertility. Lava and basalt substrates give rise to fine-textured soils, as do shales, sandstones, and limestones at higher elevations. The presence of shrubs on shallow soils usually indicates deep fracturing and weathering of the parent material.

Shrubs are more abundant on the coarser textured soils. On fine-textured soils, grasses are often dominant. Grazing favors the invasion of chaparral species, even on heavier soils.

Litter accumulates under the chaparral crown cover in significant amounts, and is important for protection of highly erodible soils on steep slopes. Accumulations in excess of 20 tons per acre have been reported.

At least 50 shrub species are reported in the chaparral type, although fewer than 15 are abundant. Most are low-growing, broad-leaved, evergreen, and either prolific sprouters or seed producers.

Shrub live oak is the most abundant species. At the lower elevations it is found with small amounts of other xeric components of the type, and also some of those of the desert shrub type. At the upper boundaries shrub live oak frequently extends as an understory into the fringes of the ponderosa pine or pinyon-juniper types. On representative areas, shrub live oak canopy cover may vary from 45 to 80 percent, with only one or two other shrub species contributing over 10 percent of the total shrub cover. It grows 3 to 8 feet tall in clumps, often with thousands of individual stems. Root crowns contain thousands of inactive buds which may sprout if the aboveground parts of the plants are killed.

Shrub live oak, because of its abundance and availability, may be an important emergency source of forage and cover for livestock and deer during winters of heavy snow. New succulent growth is readily grazed, but older growth is low in palatability. The acorns are relished by deer, turkey, and possibly other mammals and birds.

Two species of cercocarpus, hairy and birchleaf, are important browse species for livestock and deer in the chaparral. These shrubs seldom form pure stands, but may dominate localized areas. They sprout from root crowns following fire, but repeated burning diminishes their capacity to sprout.

Desert ceanothus occurs throughout the chaparral type, but is more common at the lower elevations. It seldom exceeds 6 feet in height and is relatively short lived. Although not as palatable for cattle as some other species, it has been rated excellent as a food for deer.

Pointleaf and Pringle manzanitas are common in the Arizona chaparral. They often are found in large clumps which may form impenetrable thickets several hundred acres in extent. Although these species seldom sprout, they readily reproduce from seeds and by layering. Seeds are scarified by fire, and great numbers of seedlings quickly reoccupy burned areas. Manzanitas are relatively long lived and have no forage value for most herbivores.

Skunkbush sumac is common throughout the chaparral type, but seldom contributes more than a few percent to the overstory. Fire-damaged plants sprout vigorously from the root crown. It is very low in palatability and nutritive value for most livestock and deer, but is reported to be highly palatable to goats.

Other frequent shrub species in the chaparral include hollyleaf buckthorn, Wright silktassel, cliffrose, sugar sumac, catclaw mimosa, and Emory oak. Most of these are prolific sprouters, particularly after fire, and occur in varying amounts throughout the chaparral type. Young sprouts of these species are browsed by livestock and wildlife to some degree, depending upon their abundance and that of other plants.

Much of the chaparral type is now in poor range condition. The shrub cover has increased, with corresponding decreases in the herbaceous understory. Perennial grasses which were at one time more abundant include gramas, dropseeds, threeawns, curlymesquite, bluestems, and Texas timothy. Guides developed for evaluating range condition of Arizona chaparral ranges are based on the relative abundance and productivity of desirable perennial grasses in the openings between shrubs. Additional factors considered include the density of the shrub stand, presence and degree of hedging of palatable shrubs, evidence of active erosion, and other indicators of heavy grazing.

Range Management Prescriptions

Stocking and Forage Use

Stocking rates on chaparral range must be carefully adjusted to the available forage because of the strong competitive effects of shrubs on interspersed forage grasses. If not more than 40 percent of the perennial grass production is utilized, the grasses can usually maintain themselves in a vigorous condition and provide adequate soil protection. The use of most browse species should not exceed 30 to 35 percent of the current year's twig growth.

Chaparral ranges in good condition have a grazing capacity of 5 to 15 acres per cow month or about 4 to 11 head per section yearlong. Where a combination of animals such as cattle and goats are grazed on the same chaparral range to better utilize the shrubby and herbaceous components, their numbers must be balanced with the available amounts of preferred forage for each animal. Management techniques suitable for such multiple use can be developed to increase the income compared to that from a single class of livestock. For example, goats would be a means for controlling sprout growth where fire or herbicides had been applied, and thereby encourage grass growth for cattle use.

The nutritional quality of a chaparral range is complex because of the diversity of herbaceous and woody forage. The nutritive content varies among species of plants, plant parts, and seasons of the year. Nutritive analyses and digestibility trials have been made on deer forages in the chaparral, but not for domestic livestock.

Grazing Systems

Although most chaparral ranges are grazed yearlong, some are used only for fall-winter-spring grazing. They are particularly well suited to yearlong use because of the different growth patterns of shrubs and grasses: most shrub growth occurs in spring at which time they are more palatable, whereas most grass growth takes place later as a result of summer rains. Observations indicate that both classes of vegetation would benefit from a more intensive system of grazing, but this aspect of range research has been limited in Arizona chaparral.

Summer deferment every other year on deteriorated ranges and once every 3 to 5 years on chaparral ranges in excellent condition has been recommended. A four-pasture grazing system has worked well for an operating ranch in the chaparral type west of Prescott. All cattle are kept in one pasture. Use on the four pastures is rotated so that no pasture is grazed more than half of any one growing season or the same season in any 2 successive years. Benefits of the plan after 2 years were reported as: (1) ease of looking after the cattle in a single pasture, (2) increased vigor of perennial grasses, (3) perennial grass establishment near stock water and in gullies, and (4) more even utilization.

Range Improvement Practices

Controlling undesirable shrubs coupled with seeding of various forage species may greatly increase

livestock production on some chaparral ranges (fig. 2). Furthermore, replacement or disruption of the dense shrub cover substantially increases water, reduces fire hazard, and improves access for recreation. Wildlife habitat can also be improved if the shrub-controlled area is not too large.

Numerous methods of shrub control have been tested under a variety of conditions: mechanical (cabling, chaining, railing, root plowing, bulldozing), burning, chemical, biological, and various combinations of these. Root plowing is the most effective mechanical method, but only 2 to 8 percent of the chaparral type can be safely root plowed, because of large rocks, gullies, and steep slopes. The heavy blade pulled by a tractor at a depth of from 8 to 18 inches in the soil—just below the shrub root crown—severs the crown and lifts the plants out of the ground. If properly done, more than 90 percent of the shrubs may be killed.

Herbicidal control of chaparral has been concentrated on shrub live oak, because it is the dominant species in the type and is very difficult to kill. Even with repeated annual applications that kill the aerial portions of the plant, it continues to sprout from the root crown. Picloram and fenuron appear to offer more promise for control of shrub live oak and other resistant species than the phenoxy herbicides, 2,4,5-T and silvex. Picloram and fenuron have been applied as soil drenches and also as foliage sprays. Hand application of pelleted fenuron under shrubs and trees also provides effective control and results in increased vigor of native grasses and forbs in the inter-shrub spaces. Differential susceptibility of major chaparral species to picloram and fenuron provides numerous possibilities for manipulating chaparral cover by favoring or controlling specific species.

Fire alone produces only a temporary beneficial effect, because sprouting shrubs regain their former cover in only a few years. Burning, followed by seeding of grasses and sprout suppression with chemicals, holds more promise. Many chaparral areas

Figure 2.—Elimination of chaparral (mainly shrub live oak) and seeding to grass (weeping lovegrass) can increase beef production as much as tenfold.

that have been burned and then seeded can produce large amounts of perennial grass forage if sprouting shrubs can be held to less than 5 to 10 percent crown cover.

Prescriptions for planned broadcast burning of shrubs with minimum damage to the herbaceous understory and soil require that burning be done in the fall. Specifications for successful chaparral burns are: (1) vegetation must be dormant or nearly so, and (2) optimum conditions of relative humidity range from 14 to 35 percent, fuel moisture from 8 to 18 percent, and wind not over 4 miles per hour. Burning can be successful under less than optimum conditions by pretreating the vegetation with chemical desiccants. Drying the foliage improves topkills, and also permits burning at seasons when risk of escape and damage to understory herbaceous plants is much less.

Other combinations of shrub control treatments are possible, such as mechanical-chemical treatments employing root plowing and followup spot chemical applications to control sprouts, and burning followed by placing goats on the area to browse the sprout growth. Some combination of treatments can be applied on most areas of the chaparral type regardless of topography and, in general, will produce better results than single treatments.

Seeding of native or introduced forage species in conjunction with shrub reduction is mandatory in most situations for improving condition of chaparral ranges. Seeding recommendations for the chaparral type recognize three precipitation zones and upland and bottomland sites. Recommended species include 2 legumes and 14 grasses. Recommendations for improving seeding success include selection of relatively level sites with rather deep, rock-free soils; preparation of a suitable seedbed, including removal of competing vegetation; planting of seed at a proper depth and compacting the soil over the seed (broadcasting may be feasible with small seeds); and finally, subsequent proper management of the stand once it has been established.

Where seeding has been successful, herbage production has exceeded 2 tons per acre in some cases; an increase of 1 ton per acre is common. Grass production may be expected to reach a maximum in the second or third year after seeding, followed by a decline of one-half or more from the maximum production depending upon subsequent shrub recovery. In one grazing study, 40 pounds of beef per acre per year were produced on a converted chaparral range seeded to lovegrass compared to 10.8 pounds of beef per acre on native chaparral ranges.

Range fertilization has had very little testing. It may be beneficial on some chaparral sites, but the frequent deficiency of summer precipitation considerably limits the chances for success on Arizona rangeland.

Fencing, salting, riding, and trails are accepted means of achieving better livestock distribution in the chaparral type, as they are on most range types.

Water development has increased with more intensive management and shrub conversion in the chaparral. Improved springs, windmills, horizontal wells, and earth tanks are being developed. In some cases following conversion, previously intermittent streams have become permanent, thereby creating additional water sources.

The chaparral ecosystem does not now contribute materially to water yield in Arizona, but increases following conversion of chaparral to grass approach those of pine-fir and mixed conifer sites. The large increases presumably result from reduced transpiration when deep-rooted shrubs are replaced by shallow-rooted grasses and forbs that use less water.

The chaparral yields water largely during the winter and spring. The increased water following conversion of an area to grass follows the same pattern, so that most of the increase can be expected to reach a point of use downstream.

Deer populations are relatively low where the brush is dense and herbaceous understory is sparse. Livestock and wildlife both benefit from opening up chaparral. The optimum size of opening for deer is much smaller than for cattle. The production of young, nutritious sprouts, especially if treatments were designed for periodic renewal of sprout production, would definitely provide more browse for both livestock and deer.

At present, the chaparral receives relatively little use by hunters and recreationists because of its inaccessibility. Conversion of selected areas to grass would greatly increase diversity of the ecosystem, and use by hunters and picnickers.

Additional Needed Guidelines

Use and management of the chaparral present difficult problems. Limited research and pilot trials involving conversions of chaparral to grass show we are making inefficient use of the resource. Forage production and other benefits can be increased by more effective and economical treatments designed to: (1) convert chaparral to grass or otherwise open up the chaparral stand, (2) maintain the shrub component in a new-sprout rather than a mature state, or (3) modify the shrub composition to increase the more palatable plants and decrease the unpalatable ones.

The technical information needed to fully realize the potential of the chaparral ecosystem includes: (1) refinement of techniques for prescribed burning to topkill the shrubs with minimum damage to the interspersed perennial grasses, (2) better mechanical methods of shrub control that can be applied on

most soil types and slope conditions, (3) methods to control or otherwise manipulate subsequent sprout development, (4) development of more highly selective chemicals for individual species control, and (5) techniques for establishing desirable shrubs, and more effective seeding methods.

Other problems which still stifle intensive management include: (1) how to measure shrub production, (2) tolerable levels of shrub use, and (3) optimum scheduling of use and rest for sustained grass and shrub production. Also, grazing systems are needed that take advantage of the peculiar growth requirements of the herbaceous and shrubby components, and incorporate dual use of an area by cattle and goats. The latter animals may be included in the management as a treatment mechanism which, if properly applied and managed, may materially decrease the costs of maintaining a chaparral conversion and increase the returns from the operation.

Proximity of the chaparral ecosystem to the expanding Phoenix metropolitan area will probably lead to marked shifts in priorities for the land resources. Water will continue to be a major economic product where there is opportunity for conversion of chaparral to grass, but demands for amenity values associated with urbanization also can be expected to increase in such nonconsumptive activities as hiking, photography, and picnicking. Enhancement of these attributes within the chaparral ecosystem will require sound research information.

General Characteristics

The pinyon-juniper woodland or dwarf conifer ecosystem is characterized by a shrubby tree overstory of one or more species of pinyon pines and junipers. The most common pine is pinyon, sometimes called Colorado pinyon, but Mexican pinyon is found in the southern portions of the area and single-leaf pinyon in northwestern Arizona (Little 1971). Rocky Mountain juniper is found in all States of the central and southern Rocky Mountains, but is most common in Colorado and Wyoming; one-seed juniper is an associated species in Arizona, New Mexico, and south-central Colorado. Utah juniper is common in Arizona and western Colorado. At the higher elevations, alligator juniper may be found along the Mogollon Rim in central Arizona and in the Gila and Sacramento Mountains in New Mexico.

The pinyon-juniper type generally is found from 4,500 to 7,500 feet elevation; it has been reported at 9,000 feet on the San Augustin Plains in New Mexico. At its upper limits it intergrades with Gambel oak and ponderosa pine, and at its lower limits with semidesert grass, short-grass, chaparral, or desert-shrub types.

Tree density varies from scattered individuals to several hundred stems per acre. There is usually very little understory in the latter situation. Pinyon is often more abundant than junipers at the higher elevations and in northern New Mexico and southern Colorado. Throughout most of the type, however, junipers outnumber pinyons.

Blue grama is the most abundant and frequent understory species, but other common ones include several gramas, western wheatgrass, galleta, squirreltail, Junegrass, muttongrass, Indian ricegrass, sand dropseed, eriogonum, and rough menodora. Associated shrubs are often rabbitbrush, big sagebrush, snakeweed, antelope bitterbrush, cercocarpus, cliffrose, ceanothus, and serviceberry.

Annual precipitation for the ecosystem averages from 12 to 18 inches and may reach 20 inches on some sites. Seasonal distribution is similar to that in the semidesert grass-shrub type; in eastern New Mexico, 75 percent falls during the growing season, April through September, compared to only 45 percent in western Arizona. In western Colorado about half of the 12 to 15 inches of precipitation falls in this period. Also, growing-season precipitation becomes more concentrated in the period July to September from east to west, and very little spring moisture is received. This summer monsoon pattern becomes less pronounced in northern Arizona where much of the precipitation comes from cold winter storms, and the vegetation shows affinities for the Great Basin region. In contrast, in eastern New Mexico the vegetation forms broad ecotones between pinyon-juniper woodland and Great Plains grassland.

Snow is rarely deep in the pinyon-juniper ecosystem except at the higher elevations, and usually melts in a few days, especially on south-facing slopes.

The ecosystem is found on a wide variety of soils derived from granite, basalt, limestone, and mixed alluvium parent materials. Soils vary in texture and depth, and site quality is a function mainly of depth, profile development, and precipitation.

Prior to widespread settlement of the Southwest, pinyon-juniper stands were more open and confined largely to the rocky ridges or more level sites with shallow soils. As elsewhere in the West, the great influx of domestic livestock in the late 1800's soon depleted many ranges, and forage species afforded little or no competition to tree seedlings. Due to the combination of overgrazing, absence of fires, and dissemination of seeds by mammals and birds, trees have encroached on the grasslands and original stands have become more dense.

The understory herbaceous vegetation varies according to grazing history, density of the trees, and the physical features of the site (fig. 3). Spring grazing has been particularly detrimental to cool-season grasses such as muttongrass, bottlebrush squirreltail, and western wheatgrass. These species have already disappeared from the plant community in many areas. Perennial grasses and forbs decrease in proportion to the increase in tree overstory. The effect of tree overstory on shrubs becomes pronounced when the tree canopy exceeds about 60 percent. Suppression of understory appears to be related to tree litter and root competition. The tree roots provide more competition to the lesser vegetation in the openings than directly under the tree crowns. Suppression of understory by juniper trees is most pronounced on heavy clay soils. Foliage extract of juniper also has been shown to decrease germination of gramas.

A dense tree canopy may preclude any significant changes in understory, even under protection from grazing. Where the tree cover is not too dense, midgrasses generally increase where there is protection from grazing.

Fire has been a natural ecological factor that slowed the invasion of juniper and pinyon, and converted stands of old trees to grasslands. After fire, succession begins with the establishment of annuals which reach peak production in the second and third year. Perennial grasses and half-shrubs then become prominent, followed by either a perennial shrub stage with species such as sagebrush or rabbitbrush,

Figure 3.—Pinyon-juniper woodland, the most extensive of the seven range ecosystems, may have a good stand of forage species as an understory unless the trees are too dense or grazing has been severe.

or a perennial forb-grass stage. Without recurring fires, the shrub and perennial grass stages eventually will be replaced by climax pinyon-juniper.

Pinyon-juniper ranges have been grazed by livestock for well over 200 years. Grazing continues to be an important use, and the type provides valuable wildlife habitat. Tree products are mainly firewood, charcoal, Christmas trees, and fenceposts. Harvesting of pinyon nuts sometimes provides income and recreational opportunities to local residents. Now recreational pressures, housing developments, roads, and related activities are creating serious problems in the ecosystem.

Cow-calf operations predominate in the pinyon-juniper type. Calves are dropped in the spring and marketed in the fall. Yearling operations are more common where the rancher is dependent on non-public leased grazing lands for a large portion of his annual forage requirement. Since World War II few woodland ranges have been grazed by sheep although there are opportunities for common or dual use by sheep and cattle particularly where there are numerous forbs and shrubs.

Ranch operations which depend entirely or in part on forage in the pinyon-juniper ecosystem vary in size regionally. In northern New Mexico, operations are often small in contrast to those in other areas which may often graze several hundred cattle.

Range Management Prescriptions

Stocking and Forage Use

Most pinyon-juniper ranges historically have been grazed yearlong. However, some are used only during specific seasons. Yearlong use is more prevalent in the southern part of the ecosystem; winter climate necessitates seasonal use in the more northern portions. To supplement their native forage supplies, some ranches have irrigated or improved pastures while other depend upon concentrates and roughages.

Grazing capacity of the pinyon-juniper type varies considerably with tree density, topography, range condition, and other factors. Many pinyon-juniper ranges are in only fair or poor range condition as a result of prolonged overgrazing. Most range managers consider use of the forage grasses in excess of 40 percent to be detrimental to the plant. Guidelines for woodland ranges suggest leaving one-third of the culms ungrazed at the end of the season. Average grazing capacity in the Southwest varies from 4 acres per animal unit month (AUM) on ranges in good condition to 28 acres per AUM on those in very poor condition. Differences also reflect the variable plant communities and environmental conditions over the broad geographic range of the ecosystem.

Grazing Systems

Increasingly large acreages of pinyon-juniper rangeland in public and private ownership are being more intensively managed under grazing systems other than yearlong or seasonlong. On National Forest woodland ranges in the Southwest, more than half of the allotments now are under some form of rotation, deferred, or deferred-rotation grazing; rest-rotation, which provides for at least a full year of rest for a unit, is a fairly common system. The intent is to enable the forage species to recover from the effects of herbage removal and provide for food storage, recovery of vigor, seed ripening, seedling establishment, and litter accumulation. Guidelines for summer grazing systems on woodland ranges should include resting poor condition range every summer, fair condition range every other summer, and good condition range once in 3 years.

Success of any grazing system depends on favorable moisture conditions. Although droughts are somewhat less severe and less prevalent than in the semidesert grass-shrub ecosystem, a lack of precipitation at the right times may negate what would otherwise be a successful grazing system. Forage plants will recover more rapidly from drought where provision has been made for meeting their growth requirements prior to the drought.

Range Improvement Practices

Many pinyon-juniper ranges support more livestock if improved by plant control, seeding, fertiliza-

tion, and proper management. Range seeding in the pinyon-juniper type has been successful when site selection, removal of overstory competition, seedbed preparation, selection of species to seed, and planting techniques are carefully considered. With successful seeding and subsequent proper grazing management, the additional forage supplies may well be the margin needed for the rancher to continue in business.

In some cases seeding may not be necessary if an adequate cover of native forage plants persists on the area and the overstory competition is removed. The tree overstory can be controlled by a variety of methods, from hand chopping, sawing, or grubbing to techniques utilizing various types of heavy equipment. Hand methods are practical for scattered trees on a small area, or as a cleanup in conjunction with more highly mechanized methods. Costs are high, although hand methods are considered to be the most thorough.

A crawler-type tractor fitted with various types of specialized equipment is effective for tree removal where stands do not exceed 100 trees per acre, or where tree cover is less than 10 percent. Single trees are removed by pushing them over or uprooting them with a modified bulldozer blade.

A tree crusher is particularly effective in dense stands of trees. The debris left as the crusher moves through the stand is in relatively close contact with the ground and therefore decomposes rather quickly. The debris is of a size that can be utilized readily by local residents for firewood. Tree crushing is especially suited to large areas (1) with a remnant stand of grasses and forbs that have the capacity to respond to removal of the tree competition, and (2) where esthetics is an important consideration. Crushing is limited to areas having nonstony soils and slopes of less than 15 percent.

Dragging a heavy anchor chain or cable between two crawler tractors has been used to clear many dense pinyon-juniper stands. Chaining is generally more effective than cabling. Double chaining in opposite directions is most effective for removing a high percentage of large trees and many smaller ones, especially in medium to dense stands. The method is relatively inexpensive, but regrowth and release of younger trees which the chain slides over may present a formidable followup problem. These younger trees may be harder and more expensive to treat than the original stand. Chaining followed by windrowing the debris, though most costly, is usually more effective.

Controlled burning should be considered a feasible pinyon-juniper conversion technique where vegetation is dense enough to carry a fire. Fire may be used in (1) broadcast burning, (2) killing trees invading grasslands, (3) burning individual trees, and (4) burning slash where trees were initially treated by another technique.

Dense, mature stands of pinyon-juniper can be broadcast burned during hot, dry, windy weather. The situation is hazardous and the standing dead trees are unattractive, but numerous examples show the effectiveness of such prescribed burning. Broadcast burning to control small invading trees has been tried on a limited scale. In these cases grazing must be deferred for a growing season so that enough fuel accumulates to carry the fire. Protection from grazing also is desirable for a growing season following the burn.

Individual tree burning is best suited to open stands, especially with small trees of one-seed or Utah juniper. The method is not appropriate for trees more than 10 feet tall nor for sprouting species. An advantage is that individual trees can be burned at any season.

Chemicals have not been used widely for control of pinyon or juniper trees. The chemical method is best suited to light infestations or as a followup to mechanical control where treatments can be applied to individual trees. Table 3 describes and points out the limitations of the several methods.

The range may be seeded during chaining or similar operations that sufficiently disturb the soil and provide a seedbed of mineral soil. Seed can be broadcast with a mechanized seeder and covered with a harrow, chain, or similar equipment. On large projects where areas are double chained, seed is commonly broadcast aerially between the first and second chaining.

Where trees are removed by pushing or uprooting, seed may be broadcast by hand in a followup operation. Often, seed is distributed in the pits where trees have been removed or on areas where mineral soil is exposed and disturbed.

Where the land has been cleared of debris from the control operation, seed can be drilled to increase chances of successful establishment. Although costly, plowing is most effective where it can be used for seedbed preparation and eliminating undesirable competing understory vegetation.

Other cultural practices that concentrate and conserve soil moisture usually increase the success of seeding pinyon-juniper ranges. Several mulches have proved effective, including tree branches, dead herbaceous material, plastic film, petroleum resin, and asphalt.

In northern New Mexico and Arizona, crested wheatgrass is often recommended for seeding in the pinyon-juniper type, especially where big sagebrush was the principal shrubby understory species. Weeping lovegrass is well adapted in eastern and central Arizona and areas below the Mogollon Rim where summer rainfall is high and winter temperatures mild. Other adapted species include western wheat-

Table 3.--Methods of pinyon-juniper control (extracted from Range Improvement Handbook prepared by Southwestern Region (R-3), USDA Forest Service 1970)

Method and type of equipment	Time	Limited to	Remarks
TREE CRUSHING Modified tree crusher.	Use when ground is not frozen or when excessive moisture is not present.	Large acreages of non-stony soils on slopes of less than 15 percent. Optimum benefit-cost ratio in very dense stands.	Gives good results with esthetic values.
BURNING Propane torches; fire control equipment.	Spring or summer.	Light infestations of small trees for individual tree burning. Optimum benefit-cost ratio with light stands.	Gives good results, and warrants wider use. May be used following chaining.
CHAINING (CABLING) Chain weighing 70 pounds or more per link.	Any time except when ground is frozen.	Large acreages of mature, even-aged trees. Optimum benefit-cost ratio with light and medium stands.	Fire for debris cleanup must be part of the treatment.
CHOPPING Brush chopper.	When seeding is needed, coincide with seeding time.	Little trees in small, odd-shaped areas.	Limited application; gives fair results. Poor results on alligator juniper.
ROTOCUTTER Highway-type mower. Heavy duty rotary mower.	Treat when least damaging to associated species.	Areas with small trees and no stones.	Gives good results. Will not kill alligator juniper. Desirable treatment for new invasion.
PUSHING (DOZING) Wheel or track-type tractor with blade or "stinger."	All year. Do not push alligator juniper when ground is frozen.	Light and medium stands.	Burning, windrowing, or stacking debris where necessary should be a planned part of the treatment.
HAND GRUBBING Grubbing hoe.	All year except when frozen.	Light and medium infestations of small trees.	Gives good results. Use as followup treatment or on new invasion.
HAND CUTTING Ax or saw.	All year.	Light infestations.	Gives good results except on alligator juniper, where it is ineffective. Wood products may return part of cost.
CHEMICAL SOIL STERILANT Fenuron-- Rate: Trees less than 6 ft high, 1 T. on light and medium soils; 2 T. on heavy soils. Double amounts for trees 6-12 ft high.	July to September.	Light stands only.	For other chemical treatment, see Section in Handbook on Chemical Control of Range Woods.
CHEMICAL STUMP TREATMENT Ammate crystals; or 2,4-D and 2,4,5-T with diesel; or Benzae 94.	At time of cutting.	Light stands only.	Alligator juniper only.

grass, Russian wildrye, sideoats and blue gramas, sand dropseed, spike muhly, Turkestan bluestem, yellow sweetclover, and fourwing saltbush. On good sites in western Colorado which receive more than 12 inches precipitation, the following species have shown promise: wheatgrasses (Fairway, crested, stiff-hair, pubescent, Siberian, and intermediate), Russian wildrye, Indian ricegrass, squirreltail, smooth brome, needlegrasses (subalpine, needle-and-thread, and green), some alfalfa varieties, and Siberian pea.

Limited fertilization tests have shown herbage production can be increased sufficiently to warrant doubling the stocking rate. Forty pounds of available nitrogen per acre applied for 3 years increased the gains of heifers from 23 to 48 pounds per acre per year.

Range improvement practices should be coordinated with wildlife habitat requirements by (1) not clearing slopes steeper than 15 percent, (2) leaving existing cover on northeast exposures, and (3) removing or thinning trees where they exceed 150 per acre on areas reserved for wildlife. Cleared areas should have a maximum edge effect so that deer using the created openings are never far from cover. Ideally, the openings should be not more than ¼ mile wide.

The control method chosen should cause minimum damage to browse plants on ranges important for wildlife. Burning of dense woodland on certain areas with fairly rough terrain may be an acceptable practice if sprout growth can be stimulated for the benefit of deer and antelope.

Managers should strive to maintain the cercocarpus and oak found in the pinyon-juniper type, because they contribute to deer nutrition. Habitat for desert cottontails and possibly other small animals can be enhanced by leaving down, dead trees scattered through the control area.

Opportunities for increasing water yields through manipulation of pinyon-juniper stands do not appear promising. A water yield increase of 0.45 inch (65 percent) was obtained in a single experiment in Arizona with the aerial application of a mixture of picloram and 2,4-D. Chemical conversion treatments to increase water yields cannot yet be recommended, however. The only realistic management practice for conversion is by mechanical treatments, which have not increased water yields. Clearing juniper increases water available for producing forage, but soil water storage capacity in the upper 24 inches is seldom exceeded in northern Arizona.

Additional Needed Guidelines

Present information enables the land manager to maintain the status quo for many pinyon-juniper ranges where deterioration has not progressed too far. However, additional knowledge will be required to more fully realize the potentials for improvement and multiple use outputs that exist for this extensive ecosystem. The resource manager could effectively use better environmental classifications and more accurate maps which recognize the diversity of soils, climate, and vegetation within the ecosystem. Planning must be within a holistic framework that includes more than domestic livestock considerations. Recognition of scenic values, wildlife habitat, recreation, and minimization of soil losses must be included. Demands for home sites and the attendant requirements for road construction, waste disposal, and water development plus the usual recreation-related problems must be met. Few definitive guidelines based upon sound multidisciplinary research are available to meet these needs.

CENTRAL ROCKIES PONDEROSA PINE-BUNCHGRASS ECOSYSTEM

General Characteristics

The ponderosa pine-bunchgrass ecosystem of the central Rocky Mountains occurs in a zone 5 to 25 miles wide through a change in latitude of 400 miles from New Mexico to Wyoming. The forest is found on both sides of the Continental Divide at elevations of 5,000 to 9,500 feet.

Annual precipitation varies with elevation, latitude, and longitude. West of the Continental Divide it averages from 14 to 18 inches, of which approximately 50 percent falls as snow. Through the Front Range portion of the ecosystem east of the Continental Divide, about two-thirds of the precipitation occurs in the April-to-September growing season. Annual precipitation varies from about 15 inches in the southern portion to over 25 inches in Wyoming. (fig. 4). Exposure and the base geology exert a profound influence on the vegetation and soils. North of the Arkansas River the parent materials are primarily granite with occasional extrusions of other materials. To the south, schist, gneiss, and sedimentary sandstones and shales predominate.

Figure 4.—The ponderosa pine-bunchgrass ecosystem of the central Rockies is often characterized by broken, rough topography. It furnishes forage for livestock and wildlife under the open tree canopy and in interspersed grassland parks.

Soils developed from schist have a fine, sandy loam surface soil and may be up to 20 inches deep. Subsoils are usually absent, and water penetration may be facilitated by deep weathering of the parent rock. Soils derived from granitic parent materials are extensive and range in depth up to 10 inches, usually as gravelly or coarse sandy loams. They tend to be less fertile and more erosive than other soils of the ecosystem. Shale-derived soils are usually fertile but subject to excessive sheet erosion when protective plant cover is absent. Surface soils may be up to 18 inches thick, usually with a clay to clay loam texture.

The ecosystem includes grassland parks, stringer meadows, open stands of timber with a herbaceous understory, and extremely dense stands of ponderosa pine where there is little more than a mat of needles and small twigs on the ground. In the southern and western portions of the region, oak brush occupies cutover pine sites, and in many places is of sufficient density and permanence to be classified as a distinct type.

Herbaceous communities in the pine type are often considered transitional to the ultimate climax pine forest. Certain herbaceous species appear in the later seral stages and are also characteristic understory components of the mature forest.

Generally, the Arizona fescue-mountain muhly herbaceous community is prominent in the forest understory in the southern two-thirds of the zone. As many as 35 species of grasses are present where ponderosa pine-bunchgrass ranges are in good to excellent condition. Forbs may be numerous, but fluctuate from year to year, and only a few species are abundant enough to warrant consideration. Idaho fescue replaces Arizona fescue in the northern part and upper limits of the pine zone. Thurber fescue and Idaho fescue may replace Arizona fescue in western Colorado and northern New Mexico.

Livestock grazing became important between 1880-90. By the mid-1930's, however, animal months of grazing began to decline on National Forest lands. Long-overdue recognition of the adverse effects of mismanagement on watersheds was an important factor leading to reduction in grazing.

Most of the ponderosa pine-bunchgrass lands may be used for timber production, grazing, and recreation without adversely affecting their watershed protective values. The forests are an important summer and sometimes yearlong habitat for a number of wildlife species, which can be managed in connection with timber production and cattle grazing. Where suburban recreation activities have supplanted these conventional uses, other wildlife can often be favored by application of additional habitat management practices.

Sizable acreages of the ecosystem are in private ownership, especially along streams and other productive or scenic sites. Grazing has often been severe, and corrective measures slow in emerging on many private holdings. In recent years, ranchers and public land managers have been reseeding, fertilizing, and employing various systems of grazing to

maintain and improve their ranges. On many private lands occupying the most accessible and esthetically desirable sites, uses other than grazing are assuming greater importance. Water will continue to be a primary resource, influencing all land-use activities.

Range Management Prescriptions

Stocking and Forage Use

Cattle grazing is seasonal on most ponderosa pine-bunchgrass ranges of the central Rockies. Grazing may be either continuous from late spring to late fall, or restricted to shorter periods by dividing the area into a number of units and moving the livestock among them during the grazing season.

Utilization of 30 to 40 percent of the current annual growth of the major forage grasses provides maximum sustained production of both forage and beef on ponderosa pine-bunchgrass ranges. Lighter rates reduce total livestock production, although individual animal weight gains are greater. Grazing the major grasses in excess of 40 percent will damage the range and eventually lower livestock production.

Most livestock graze in the open grassland parks within the ponderosa pine-bunchgrass ecosystem. Some use is made of the open timber type, but cattle seldom graze within dense timber where forage is sparse. From 2 to 3 acres per animal unit month to as many as 8 to 15 acres/AUM are required depending on slope, range condition, and the combination of associated cover types. About 10 acres/AUM are required where cows and calves are grazed on range in fair condition.

The forage is usually ready for grazing between June 1 and 15, and may be grazed as late as November. Animals seldom gain weight after September, however, on native bunchgrass herbage. Nevertheless, crude protein and phosphorus content of native forage in the ponderosa pine type appear to be at least adequate for grazing animals 8 months of the year.

A range with a large percentage of the forage comprised of Arizona fescue, sedges, or little bluestem would best be used early because of seasonal development of forage. Ranges that have a predominance of mountain muhly are more suitable for mid- to late-season grazing, when this species reaches its maximum production.

Grazing Systems

Bunchgrasses provide much of the forage. Since they reproduce from seed, management should try to encourage reproduction of desirable species. As on other ecosystems, cattle graze the range selectively, consistently eating certain plants on certain areas more than others. The manager can attempt to disrupt or alter this pattern to obtain more use of all plants present. While seasonlong or continuous grazing is common, some form of rotation and/or deferred grazing is also used. This includes variations of the rest-rotation system proposed by Hormay and Talbot (1961), which was developed on a pine-bunchgrass range in California.

Some stockmen have voiced concern that frequent livestock movements or changes in the available forage gives lower cattle weights than where animals graze an area seasonlong. Systems of management that recognize the physiological requirements of the forage species usually benefit the range. The synergistic effect of better overall management very likely contributes to range improvement with the adoption of a more intensive system.

Range Improvement Practices

Some grasslands within the ponderosa pine ecosystem were cultivated for various agronomic crops for a number of years, then abandoned by early settlers. Plow lines on these areas are often apparent almost 100 years later, and poor forage species still predominate. Elsewhere, heavily grazed open parks also often support only poor forage species. Seeding of a variety of forage species can restore these areas to a highly productive condition in a few years (fig. 5).

Research emphasis on seeding of depleted ponderosa pine ranges has centered largely on planting techniques, species adaptability tests of both native and exotic species, and management aspects such as season and intensity of use. The results have provided sound recommendations of when, where, what, and how to seed. The most promising species for Colorado are listed in table 4.

Seeding success was closely related to the degree of seedbed preparation and removal of competing vegetation. Seedbed preparation with a moldboard or brushland plow, or a heavy offset disk has often resulted in excellent stands.

Early spring and mid- to late-fall plantings have given the best stands in lower elevations of the pine zone in Colorado. In the upper part of the zone, seeding in April and May or September and early October on well-prepared seedbeds is usually best.

Management studies on seeded areas have shown a mixture containing crested wheatgrass with yellow sweetclover plus smooth brome or intermediate wheatgrass as secondary species can be recommended for sustained forage and livestock production in the Front Range. Once established, grazing of these ranges can begin in the spring when maximum leaf length of crested wheatgrass plants

Figure 5.—Grassland parks in the ponderosa pine-bunchgrass ecosystem can be returned to a productive condition by seeding one or more forage species.

Table 4.--Success of six species used in range seedings in the ponderosa pine zone

Species	Times seeded	Seedings by class				
		Excellent	Good	Fair	Poor	Failure
Crested wheatgrass	265	64	127	27	21	26
Smooth brome	195	31	88	25	24	27
Yellow sweetclover	153	17	60	26	30	20
Alfalfa	34	4	25	--	1	4
Timothy	16	--	8	2	4	2
Intermediate wheatgrass	13	7	5	1	--	--

averages approximately 4 inches. They can continue to be grazed seasonlong to a 2-inch stubble height, which is approximately 65 percent of the total forage weight.

Crested wheatgrass stands have been grazed to a 1-inch stubble in the spring or fall without depletion. In New Mexico, utilization of up to 77 percent of the herbage had no deleterious effect on crested wheatgrass stands grazed only in the spring.

For very early feed, Russian wildrye may be seeded in pure stands in the Front Range. Animal weight gains will usually be smaller than on ranges seeded to a mixture of species, however. Grazing to approximately a 3-inch stubble height is recommended for Russian wildrye to avoid development of ungrazed wolf plants and local overgrazed areas.

Seeded stands of Sherman big bluegrass produced the highest total beef production and grazing capacity of any seeded species tested at Manitou Experimental Forest near Colorado Springs, Colorado. Special care must be exercised to avoid planting seeds too deeply. To insure successful establishment, seeds should be planted into a moist, well-prepared seedbed in July or August.

The grazing season in which animals make good gains can be substantially increased by including seeded ranges in the management system. Combinations of seeded and native range provide sufficient nutrients 10 months of the year.

Cultural practices such as the use of herbicides and range fertilization can also improve these ranges and increase grazing capacities. Severely depleted ranges are most responsive to these kinds of treatment.

Several widely recognized range management practices also are applicable to ponderosa pine-bunchgrass ranges: fencing for better livestock control and distribution, development or hauling of water, movement of salt grounds to encourage uniform use, range-riding and construction of trails and driveways to move livestock and improve range accessibility.

Additional Needed Guidelines

Managers and users of ponderosa pine-bunchgrass ranges in the central Rockies have knowledge available that enables them to satisfactorily manage the grazing resource for livestock production. However, additional constraints on conventional uses of this forest-range ecosystem are complicating management. For example, range livestock operators and public land managers are required to provide in their management plans for integration of the multiple products and values that are available in the ecosystem. Because much of the ecosystem is close to population centers and is readily accessible, management must now also accommodate intensified demands for subdivision development, esthetics, wildlife, and a variety of recreation activities.

It is within this framework that research must concentrate on developing, testing, and evaluating knowledge applicable to multidisciplinary management. Prerequisite to it is a comprehensive appraisal of the ecosystem components and their inherent productive capabilities. Land managers must be able to understand and predict the interactions and responses of the abiotic, biotic, and socioeconomic components affected by various management prescriptions.

General Characteristics

The ponderosa pine-bunchgrass ecosystem in Arizona extends from approximately 6,000 to 9,000 feet, varying according to slope and exposure, It is the major forest ecosystem in the State, and, although widely scattered, the bulk of it is found in central Arizona as an unbroken stand for nearly 225 miles. Ninety-six percent of the commercial forest area is in public ownership.

Moisture, which is commonly limiting, comes in two pronounced periods (winter and summer). In the summer, moisture-bearing winds from the Gulf of Mexico result in frequent, high-intensity, localized thundershowers in the mountainous region of central and southeastern Arizona. Winter precipitation is primarily from storms that move inland from the Pacific Ocean, and drop most moisture as snow in the high mountains of the central and northern parts of the State. Annual precipitation averages 20 to 21 inches, with a range of 19 inches to 25 inches.

Much of the ecosystem occurs on the relatively flat topography of the Colorado Plateau Province, and in an altitudinal belt on the isolated mountains of the Basin and Range Province across southern Arizona and New Mexico. The sedimentary formations of the Plateau are interrupted by igneous structures, including some large central-type volcanoes, numerous cinder cones, and lava-capped plateaus.

Soils on which the ecosystem has developed are derived from both igneous and sedimentary rocks. Soil characteristics that influence available moisture tend to be the most important to the vegetation. The more porous soils are generally more productive.

Soils on the Colorado Plateau vary from fine to moderately coarse-textured sandy loams, often with clay loam to clay subsoils. Frequently they contain admixtures of gravel and large volcanic boulders. In some areas, cinders of varying depth overlay a fertile clay soil.

Within the Basin and Range Province, surface soils are mainly sandy loams which vary in depth. Many are gravelly, stony, and porous. Rock outcrops are frequent.

Ponderosa pine forest occurs mainly in uneven-aged stands of small even-aged groups ranging up to several acres (fig. 6). In central and northern Arizona north of the Mogollon Rim, the ponderosa pine forests usually contain few trees of other species, and often appear parklike with a grass understory. The southern forests tend to have a more complex composition of conifers and hardwood; parklands with grass and/or shrub understories are rare. In climax forests understory shrubs may be lacking to fairly common. A number of perennial forbs are typically

Figure 6.—Southwestern ponderosa pine occurs as irregular, uneven-aged stands consisting of small even-aged groups. Herbaceous understory is prominent where the tree canopy is not too dense.

found in the ponderosa pine forests more or less throughout the State.

The characteristic grass aspect of the understory of ponderosa pine forests on the Colorado Plateau is dominated by Arizona fescue and mountain and screwleaf muhlys. Other species may be abundant locally or scattered through the understory cover. The vegetation type supports populations of elk, mule deer, turkey, and tassel-eared squirrels.

The successional pattern of the major portion of the type progresses through eight stages, from annual plants to the stage where the site is dominated by long-lived trees with a herbaceous bunchgrass understory. Because livestock grazing exerts a selective influence upon herbaceous plant communities, the prevailing plant life-forms of each lower successional stage is progressively less susceptible to grazing damage. Species which either escape or withstand a high degree of grazing abuse may persist as minor components of the herbaceous composition of the more advanced successional stages.

Secondary succession of the understory may or may not retrace the course of deterioration, and may

require many years even under improved livestock management. On sites protected from grazing, perennial grasses may become reestablished simultaneously with various perennial forbs and half-shrubs. Ponderosa pine seedlings may become established during the early stages, and the forest opening can progress directly to a forest-dominated condition.

As forest density increases, production of the herbaceous understory may decline from 1,000 pounds per acre in forest openings to 50 pounds per acre in dense stands. This inverse relationship is generally curvilinear. Overstory reduction usually brings a rapid response of herbaceous vegetation. Herbage production peaks about 6 years after logging, and on selectively logged areas will exceed that of unlogged areas for 11 to 15 years. The largest herbage response to annual weather differences can be expected where timber overstory dominance is minimum.

Fire in the southwestern ponderosa pine type has been a subject of controversy. Some have felt that fire has resulted in reduced timber production, while others claim that periodic natural fires have been important in developing and maintaining the "normal" stand structure of the type. The change since the early 1900's from open stands to dense thickets of young trees has been in part due to protection of the forest from fire. Fires cause the greatest damage in these stands.

A wildfire on the Wild Bill Range in Arizona caused almost complete mortality of trees in an unthinned young stand (126 square feet per acre basal area), but no significant reduction where the stand had been previously thinned to 20 square feet basal area per acre and the fire remained on the ground. There were large increases in forage production for livestock and wildlife where the tree canopy was eliminated. However, the postfire production was approximately the same on both the burned and unburned areas of the thinned stand. Where the burned, unthinned stand was seeded to orchardgrass and intermediate wheatgrass, herbage production exceeded 1,000 pounds per acre, ovendry, or approximately 400 pounds more than the unseeded area.

Prescribed burning for fuel reduction and silvicultural purposes also benefits forage production and utilization in moderate to dense stands. Experiments suggest that the fire should consume the total depth of the forest floor to increase herbage production appreciably.

Information on forage nutrition of Arizona ponderosa pine ranges has been developed at the Wild Bill Range. Crude protein is consistently higher in forage growing in the open as compared to that under a timber overstory. After peaking in June, it steadily declines through the summer season. The seasonal trend and overstory relationships for phosphorus in the forage are less consistent. No seasonal or overstory trend was detected in mineral content of the forage.

A large portion of the Arizona ponderosa pine ecosystem is grazed in the summer. Cold temperatures and deep snow generally preclude its use at other times. However, some National Forest allotments in the more southern portion of the region are used yearlong or in other seasons.

Few data are available on the economic and operational characteristics of cattle ranches in Arizona and New Mexico which are specific for ponderosa pine bunchgrass ranges. Size of the ranch operation and carrying capacity of the land both strongly affect the cost efficiency of producing beef. Ranches averaging 200 animal units (AU) do not have the income to pay interest costs nor do they provide a full return to labor. Ranches do not attain near maximum economics of scale until they reach about 800 AU.

How grazing affects water yield and quality is an important question, as the ponderosa pine type is the source of nearly half the streamflow in the Salt River watershed in Arizona. Grazing a watershed in Arizona that was converted from ponderosa pine to a grass cover has not resulted in increased water yield.

This lack of response, which was obtained on heavy-textured volcanic soils, has not been consistent on sedimentary soils. The effects on erosion and sediment movement are likewise variable. The effect of fecal contamination of water when riparian habitats are grazed is unknown.

The primary impact of grazing on timber production is the potential damage to regeneration, especially where grazing is excessive. Often, intensive silvicultural management can benefit both timber production and forage production.

Parks and forest openings in the Arizona ponderosa pine type are preferred by cattle and elk, and if they are not too large, by deer also. The mutual preference creates potential for competition. Intensive livestock grazing can cause both deer and elk to avoid an area, but light to moderate grazing may have little effect on big-game animals.

Range Management Prescriptions

Stocking and Forage Use

Ponderosa pine naturally grows in groups with interspersed small forest openings and larger open parks. Grazing is normally most intensive in forest openings or where the forest canopy is sparse.

Factors that influence grazing of pine-bunchgrass ranges include: (1) distance from water, (2) steepness and length of slope, (3) trails and other access routes, (4) density of the timber stand, (5) floristic

composition and season of use, and (6) range condition.

Range condition is related to the kind and abundance of perennial bunchgrasses. As less desirable species that escape or withstand heavy grazing become more prominent, range condition declines. Increasing timber density has little effect on the floristic composition of the herbaceous species.

Arizona fescue flowers about 1 month earlier than mountain muhly, similar to the development of the two species in the pine-bunchgrass type of the central Rockies. This flowering difference is reflected in the seasonal forage preferences of the grazing animals. In northern Arizona, Kentucky bluegrass, Arizona fescue, and mountain muhly are preferred species, while blue grama and prairie Junegrass are least preferred. Proper grazing of the forage species on Arizona ponderosa pine ranges appears to be about 30 to 40 percent.

Grazed-class photo guides and grazed-plant methods are useful in estimating forage utilization. On National Forests in the Southwest, zones of forage production and utilization are mapped from ocular estimates and clipping and weighing herbage over several seasons. Actual stocking records combined with these map records provide a basis for arriving at proper stocking.

Grazing capacity varies considerably, but potential carrying capacities of Arizona ponderosa pine ranges have been estimated at 5 to 8 acres per animal unit month. Averages on National Forest land by condition class range from 7 acres per AUM for range in good condition to 41 or more acres per AUM on the poorest ranges. Approximately 45 percent of the ponderosa pine range is in less than fair condition.

Grazing Systems

Several authors have recently reviewed the value of specialized grazing systems. Advantages and disadvantages encountered on Arizona ponderosa pine ranges are similar to those on other range ecosystems.

Most systems provide for (1) periodic deferment or rest to allow desirable forage species to regain vigor, (2) more uniform use of the forage resource through better livestock distribution, and (3) the integration of seeding and control of undesirable species into the grazing plan without additional fencing for grazing control. The expenses of additional livestock water and for the additional units that are required must be anticipated if a specialized system is adopted. Major points to consider in selecting a grazing system include:

- Kind and class of animal to be grazed.
- Kind, amount, and phenology of vegetation.
- Amount and seasonal occurrence of rainfall.
- Topography and elevation.
- Length of growing season.
- Kind and characteristics of soil.
- Costs for fencing, water development, and other range improvements.

Range Improvement Practices

Forage yields on ponderosa pine ranges can usually be improved by management practices designed to improve range condition trend. Where improvement is apt to be slow, seeding of desirable forage species can rapidly restore range productivity, correct seasonal deficiencies in forage supplies, and retard erosion on disturbed sites such as logging roads or recently burned areas.

Undesirable plants are often not the serious problem they are on other range ecosystems. However, removal of competing vegetation is recommended for seeding success. Selection of potentially productive sites, proper planting of adapted species at the proper season, and the use of viable seed are also basic to seeding success.

Disk-type plows have generally proved best for preparing sites and removing competing vegetation without excessive disturbance of the seedbed. Seed should be drilled wherever possible.

Seeding rates vary by species, but generally average 8 to 10 pounds per acre. Plantings from about the middle of June to the middle of July, just prior to the summer rains, have been most consistently successful in New Mexico and Arizona. In some areas, fall or early spring seeding can be recommended where seedlings can be sufficiently established to survive the late spring-early summer dry periods. The species to be seeded should be selected in part upon the forage requirements of the management plan, including when they will be grazed. Generally, crested wheatgrass and intermediate wheatgrass have shown the widest range of adaptability. Once established, big bluegrass can produce outstanding yields. In areas with annual precipitation above 25 inches, orchardgrass, smooth brome, and tall oatgrass may produce a more palatable and nutritious forage; 18 inches of precipitation may be sufficient to establish stands of orchardgrass and tall oatgrass.

On disturbed sites, long-lived sod-forming grasses such as intermediate wheatgrass and smooth brome will give maximum protection. Where quick, but temporary, erosion control is needed until pine seedlings are established, short-lived grasses, sweetclover, and annual mustards should be considered.

New plantings need protection for at least the first two growing seasons. Thereafter, the seeding should be grazed and managed so that forage production can be maintained. Other techniques for improving forage yields include fertilizer applications and water

spreading. There has been little documentation of the effectiveness of these techniques in the Arizona ponderosa pine type, however.

Additional Needed Guidelines

Emerging demands for the range resources in the Southwest appear to be dominated by the quests for recreation and maintenance of environmental quality. The ponderosa pine ecosystem is increasingly popular for people seeking escape from the heat in the desert metropolitan areas. Concomitantly, the public is becoming more cognizant of the management of these lands in public ownership.

The recreational opportunities of these rangelands may provide more economic benefits to the rural communities than attempting to attain maximum livestock production. Range livestock operations, maintenance of environmental quality, and other uses of ponderosa pine-bunchgrass ranges are seldom incompatible if the resource is wisely managed.

A thorough knowledge of the managed ecosystem is necessary to achieve an optimum combination of uses. The resources need to be characterized, classified, inventoried, and monitored. With such a base, they can be adapted to new or changing programs and policies, and more intensive management practices.

More detailed information is needed, however, on the beneficial and detrimental effects of grazing in relation to wildlife populations and recreational use of ponderosa pine ranges. In addition, more specific knowledge is needed about which grazing system will bring about the most rapid recovery of range condition for different condition classes across broad site (or habitat-type) differences on Arizona pine-bunchgrass ranges.

An optimum combination of uses requires a more refined analysis of the social and economic aspects of range use of the ponderosa pine ecosystem. Investment and returns for entire ranch operations as well as specific management activities and improvements must be meshed with the constraints that are being placed on the historic uses of the resource, particularly that in public ownership.

MOUNTAIN GRASSLAND ECOSYSTEM

General Characteristics

Mountain grasslands are intermixed with timber stands between the upper limits of the ponderosa pine forests and the alpine ecosystem, usually at elevations from 8,000 to 11,500 feet. They are associated with spruce-fir, lodgepole pine, and aspen forest types in Wyoming, Colorado, New Mexico, and Arizona (fig. 7).

These forest types occupy an estimated 15 million acres in the central and southern Rocky Mountains; mountain grasslands comprise not more than 10 percent of the total.

Long winters with deep snow and short, cool growing seasons characterize the climate. Average annual precipitation varies from 20 to 40 inches. Summer rainfall averages 6 to 10 inches. During the warmer summer months, temperatures average about 50° to 55°F.

Snowmelt during April or May usually saturates the soil mantle. With rising temperatures in late spring, plant growth is rapid and reaches its maximum biomass in late July. Killing frosts usually occur by early September.

Soils of mountain grasslands are variable due to diversity of parent materials and the complex geomorphic conditions under which they developed. They resemble prairie soils in that the A-horizon is dark brown, relatively high in organic matter, slightly acid, and usually well drained.

An extensive segment of the mountain bunchgrass community is characterized by Thurber fescue. This species is often dominant from southern Wyoming southward through Colorado into northern New Mexico and Arizona. Thurber fescue is sensitive to heavy grazing, however, and may be replaced by several other small bunchgrasses.

Another segment, the Wyoming bunchgrass community, occurs to the north in the central Rockies. Idaho fescue associated with bluebunch wheatgrass and sagebrush typify the plant cover. The vegetation may vary greatly with changes in soil texture or exposure; less conspicuous differences occur with gradual changes in elevation or other features of the environment.

Encroachment of trees on typical grassland sites is slow because of strong competition for moisture from the large, vigorous bunchgrasses and other herbaceous plants, low temperatures, soil heaving, and other limiting factors. Fire also may play an important role in restricting the invasion of trees. Where grasslands intermingle with forests, differences in site characteristics are usually less pronounced.

Figure 7.—Mountain grassland parks occur intermixed with high-elevation forests.

Floristic composition varies with site characteristics and grazing history. Forbs tend to be more prominent at higher elevations, however, and shrubs at lower elevations within the mountain grassland zone. Forbs are characteristically absent from bunchgrass ranges with a long history of sheep use. Interstices between the grass plants are occupied by litter or bare soil. Annual plants seldom are abundant except on recently disturbed or severely overgrazed areas.

Herbage production of 1,000 to 2,000 pounds per acre is common on mountain grasslands, and yields occasionally exceed 3,000 pounds per acre. Productive sites usually support a relatively dense cover of bunchgrasses and tall forbs; shrubs may be locally abundant.

Mountain grasslands in the central Rockies were initially grazed by domestic livestock about 100 years ago. By 1900 practically all of the available high-elevation lands were being grazed, and some already had been overgrazed. Regulation of grazing on them began with establishment of the National Forests in the early 1900's. However, these and other rangelands received maximum use in meeting the demands of World War I. Present use of National Forest rangeland in the West is only about one-fourth of the former high level. Nevertheless, the grazing of high-altitude rangelands continues to be essential for meeting the annual forage requirements of many livestock ranches in the central Rockies. Most of these ranges are grazed by cattle, although they provide nutritious forage for sheep as well.

Mountain grasslands and adjacent forests also provide habitat for game and nongame animals. The use of these areas by wildlife is influenced by the manner and degree to which they are grazed by livestock. Elk will graze with cattle during the summer where there is an adequate food supply.

Livestock grazing enhances the scenic interest and attractiveness of mountain grasslands to some people. To others, livestock are a nuisance, especially in the vicinity of campgrounds; sometimes there is mutual disturbance. Recreation developments may reduce the amount of rangeland available or suitable for grazing, but in general, conflicts between grazing and recreation do not appear to be serious or widespread.

The mountain grassland ecosystem of the central Rockies is an important source of water to millions of people hundreds of miles away. It is locally important for many small communities. Consequently, management practices which impact upon the storage and delivery of water for downstream domestic, industrial, and agricultural uses are of critical significance.

Range Management Prescriptions

Stocking and Forage Use

Present knowledge is generally adequate for deciding what constitutes a permissible level of grazing on mountain grassland. Use of the more productive and palatable grasses, such as Idaho fescue, should not exceed 40 to 45 percent on range in good condition grazed seasonlong. Palatable and nutritive forbs also may comprise a sizable and valuable part of the cattle diet. To utilize this class of forage more fully, stocking may be somewhat heavier earlier in the grazing season than in the fall when many forbs dry and shatter. Grass use in fall tends to increase as forbs become less readily available. Bunchgrasses produce little regrowth when they are grazed after flowering. Under continuous, seasonlong use, the grazing capacity of mountain grassland in good condition is about 1.5 acres per animal unit month. About 2.5 acres per AUM may be a reasonable overall estimate for the type.

Contingent upon the depth of the snowpack and the rate at which it melts, most ranges are ready for grazing between mid-June and mid-July. Range readiness guides for mountain grasslands usually stipulate that important perennial grasses be headed out and that the soil be sufficiently firm and dry to avoid trampling damage. Grazing is often terminated in early fall, but may be dictated by weather and/or quantity and quality of forage.

As on other ranges, selective grazing on mountain grasslands may weaken the more palatable plants and favor the less palatable ones. Because of the competitive advantage thus gained, nonpalatable plants often become more prominent on heavily grazed ranges. Discontinuance or reduction of grazing may serve only to retard or prevent further range deterioration without necessarily shifting the competitive advantage to palatable plants over a short time span. Consequently, relatively unpalatable plants may persist for years.

Range deterioration is indicated by many changes. In its early stages, an increase in forbs or secondary smaller grasses usually accompanies a decrease in primary grasses such as Thurber fescue and Parry oatgrass. Total cover may change very little, and occasionally it increases. Herbage production and litter tend to decrease slightly, and bare soil increases. In more advanced stages of deterioration, reductions in ground cover and herbage yields become more pronounced. Less evident, but equally important, are changes in plant growth and site characteristics. For example, there may be changes in (1) plant vigor of the major forage species, usually expressed through a reduction in the number and height of grass flower stalks or length of leaves, and (2) soil stability, as evidenced by litter accumulation,

surface runoff, and erosion. Other factors sometimes considered are changes in size of grass clumps, abundance of plant seedlings or young plants, frequency of dead or dying plants, arrangement of plant colonies, amount of forage produced, and current degree of grazing.

Grazing Systems

For many years, mountain grasslands were grazed closely and continuously from the time snow melted until snow or cold weather forced livestock to lower elevations. Continuous grazing but with more moderate stocking is still widely practiced from the time the range is ready until fall. This system is best suited to small range units in relatively good condition. An advantage claimed is that cattle gain more weight than under other systems which require periodic movement of the herd. Areas of livestock concentration may be a problem, however, and palatable plants may be overgrazed and soil erosion increased as a consequence of topographic features, vegetation patterns, and watering places.

Various systems of grazing have been advocated, primarily to improve range condition and obtain more uniform use of the range. Some form of a rotation, deferred-rotation, or rest system can be employed to advantage on most ranges large enough to justify subdivision and development of necessary stock water. Decision as to the best system must be based on local conditions and circumstances.

Desirable features of these more intensive systems are: (1) from a biologic standpoint, they periodically rest important forage species from grazing during the growing season, and (2) from a management standpoint, they provide more uniform use of the range when it is grazed. Range units stocked heavily for a short period usually provide more usable forage than if stocked more lightly for a longer period. Furthermore, control of undesirable range plants and range seeding usually require protection from grazing for a year or so, but additional fencing to protect the investment may not be needed when the area is integrated into a grazing system that provides for periodic nonuse of the range.

Fencing of mountainous rangeland is expensive, and may preclude intensive management systems on some areas; costs of fencing range from $1,500 to $2,200 per mile. Adoption of a system may further be restricted by differences in elevation and plant development, natural barriers, unequal distribution of vegetation types, and other factors that do not allow individual units to supply their share of forage when needed.

Range Improvement Practices

Seeding of mountain grasslands may be needed and justified if satisfactory range condition cannot be restored within a reasonable time through grazing management or control of undesirable plants. Scarcity of desirable plants, suitability of the site for seeding, need for additional forage or ground cover, ability to protect and manage the seeded area, and costs and returns from seeding are factors to be considered. An estimated 5 percent of the mountain grassland area in Colorado is in need of seeding, and most of the better sites can be seeded on the basis of available guidelines. Numerous species are adapted to mountain grassland sites. Seeding costs have been estimated at $5.50 to $8.50 per acre.

Guidelines are available for controlling several noxious species on mountain grasslands. Spraying to control broad-leaved species and increase grass production has coincidentally reduced pocket gopher populations by reducing their food supply. However, herbicidal control of certain poisonous plants, particularly larkspur, has been generally ineffective or impractical.

Rangelands sprayed with herbicides are often protected from livestock for 1 to 3 years to obtain the greatest possible recovery of the forage grasses. Recent findings indicate that comparable improvement may be obtained under moderate grazing without rest.

Mountain grasslands provide nutritious forage for livestock during most of the summer grazing period. However, nutrient content of the forage and animal weight gains decline with advance of the season, and may approach minimum levels recommended for maintenance of cattle before the animals are taken to lower ranges in the fall. Grass yields, crude protein content, and palatability may be increased under certain conditions by fertilizing the range with nitrogen. Nitrogen generally favors growth of grasses, while phosphorus and potassium encourage growth of legumes. Ample soil moisture is required for fertilizer to be effective. On relatively infertile soils, best results may be achieved by fertilizing in conjunction with the control of noxious plants.

Dead organic matter may accumulate in dense, lightly grazed stands of Thurber fescue. Buildup of litter lowers soil temperature, which in turn reduces bacterial activity, ties up nutrients, and slows the general nitrogen cycling process, particularly during cool, wet years. Under such conditions, burning may increase the quantity or improve the quality of forage. Certain rodents, which tend to become more abundant with increases in litter, possibly could be reduced through prescribed burning. Prescribed burning also offers a potential means for controlling grassland insects and diseases.

Practices to improve cattle distribution and the usability of mountain grasslands are similar to those described for other ecosystems. Rough topography and elevational differences, which noticeably affect plant development, complicate distribution and management of livestock.

Additional Needed Guidelines

Livestock grazing is desirable on mountain grasslands. Even though its contribution is comparatively small in the national context, these ranges provide a valuable segment of the annual forage requirements of many ranch operations which furnish calves as feeder animals to help supply the nation's demand for beef. Other demands for mountain grassland products and attributes can be expected to increase, however, and adjustments in livestock grazing will be needed to accommodate those uses.

Management of the resources of the subalpine zone have been largely single-use oriented; that is, wood products from the forest and livestock products from the intermingled grasslands. Much of the knowledge necessary for efficient, single-use management is available, but not all is readily accessible to the land manager. Moreover, this information is needed in a context that illustrates how various land management practices influence the productivity and quality of all resources, the complex processes and interactions involved, and the balance of uses and products.

Within this framework, specific areas are in need of further amplification and/or refinement. Understanding of the vegetation/soil responses under various grazing systems that might enable earlier use of the range is needed to insure maintenance of inherent site productivity. Similarly, improved guidelines for estimating site capability are needed to complement estimates of carrying capacity of areas for livestock, wildlife, and people. Also, the influences of fire, phytotoxins, rodents, and soil characteristics on composition and succession of mountain grassland vegetation deserve further study.

Opportunities for, and long-term effects of, range improvement through manipulation of individual species, or groups of plants, need exploration. For example, research is needed to determine methods for controlling or replacing less desirable species with more desirable ones, to meet not only the requirements of livestock but also those of recreationists and wildlife. Furthermore, the responses of seeded ranges to different systems of grazing need to be determined in conjunction with the economic evaluation of seeding. Information is also needed that will insure rapid revegetation of areas disturbed by ski developments, road construction, or other peculiarly difficult sites. Much remains to be learned about the potentials and limitations of plant cover manipulation, and their overall effects on the environment.

General Characteristics

The alpine ecosystem occurs from the upper limits of tree growth to the mountain peaks, which may exceed 14,000 feet in the Rocky Mountains (fig. 8). The transition from forest to alpine may be abrupt, or it may be a rather broad ecotone marked by low-growing, poorly formed trees interspersed with characteristic herbaceous and shrubby alpine species. In the Rocky Mountains the alpine is usually above 11,800 feet in northern New Mexico, 11,000 feet in northern Colorado, 9,800 feet in northern Wyoming, and as low as 7,500 feet in northern Montana.

Figure 8.—Low-growing herbaceous and shrubby species characterize the alpine ecosystem above the coniferous subalpine forests.

The alpine landscape is often characterized by rugged, broken topography with rocky, snowcapped peaks, glaciers, spectacular cliffs, and talus slopes. Many areas, however, are gently rolling to almost flat.

Alpine soils are, in general, much less uniform than the soils of lower, level areas. Part of this nonuniformity is due to the great variability of terrain, and part to the strong freezing and thawing processes responsible for stirring and sorting the soil and rock fragments. Soils range from rocky and gravelly lithosols with little or no development to boggy, organically derived peats. Mineral soils on well-drained areas with a good vegetative cover generally show considerable profile development. Permafrost may be present at relatively shallow depths.

The most important factor controlling the distribution and growth of alpine plants is available soil moisture. Soil moisture depends to a large extent on the snow accumulation pattern, which results from the interaction of wind and topography.

Precipitation during the growing season may have little effect on the growth of alpine species. Often it comes as high-intensity rains with consequent high runoff and lack of penetration into the root zone.

The alpine zone is seldom without wind; average windspeeds of 25 to 30 miles per hour are common. Wind not only influences the snow distribution pattern of the alpine zone, but plants are killed or damaged both by mechanical abrasion from wind-driven soil particles and by desiccation. Wind erosion removes the fine soil particles and leaves coarser particles as mulch.

The temperature regime is highly variable, but low temperatures are characteristic. Temperatures at or near the ground surface may be relatively warm, however. There is a marked diurnal temperature regime, and a pronounced shady slope-sunny slope variation.

In comparison to more complex floras of lower elevations, usually no more than 200 to 300 species are present in the alpine zone of a given mountain range; many of these are common to most alpine areas of a region. Grasses and sedges are almost ubiquitous. Additional families with wide alpine distribution are saxifrage, rose, mustard, buckwheat, and pink. Usually these are represented by herbaceous perennials with large root or stem storage systems. Annual plants are rare. Most shrubby species are members of either the willow or heath families. The shrub life form is not common, however.

Little is known of the environmental conditions necessary for successful reproduction. Seed production and seedling establishment are sporadic because growing season conditions are frequently unfavorable, although in some years abundant seed crops are produced. Seedlings become established both in open areas and within the crowns of other plants, particularly low-growing cushion plants.

Biomass varies considerably from year to year and from site to site. Xeric, exposed sites often produce less than 100 pounds per acre aboveground, while on more favorable sites production may exceed 3,000 pounds per acre. Mesic turf sites will average between 900 and 1,800 pounds per acre.

About 80 percent of the biomass of alpine plants is below ground. Forbs appear to have a proportionally greater amount of underground biomass than grass or grasslike species.

The alpine growing season is only 30 to 75 days long, but the rate of increase of standing crop may exceed 50 pounds per acre per day. This rate is comparable to that of many low-elevation communities.

Alpine species seem to have a wide ecological amplitude, and can occupy what appear to be diverse habitats. The classic concepts of climax and succession as developed in warmer, low-elevation regions do not appear to be applicable in the alpine zone.

Most of the alpine zone is in public ownership. Sheep are the principal domestic livestock that graze the alpine allotments; cattle grazing is limited because cattle are subject to heart damage (brisket disease) on high-altitude ranges.

The number of sheep grazing the alpine allotments in the central and southern Rockies has declined steadily since World War II. Inaccessibility, high costs of operations, shortage of dependable herders, market conditions, and closures of allotments to domestic sheep grazing for range protection have contributed to the situation.

Sheep diets usually consist of a relatively large number of species, which provide high-quality forage. Overall, forbs make up the bulk of the diet, the proportion being related to their relative availability. Consumption of grasses and sedges increases in the latter part of the grazing season as forbs mature.

A number of large and small mammals and birds utilize the alpine ranges for summer habitat, while others are residents throughout the year. Common species include elk, deer, mountain sheep and goats, pika, marmot, pocket gopher, and ptarmigan.

Range Management Prescriptions

Stocking and Forage Use

Alpine ranges have been grazed by sheep since the late 1880's. As numbers of domestic livestock increased on the western range, animals moved to higher elevations, more or less following the receding snow line each spring. Sheep were usually grazed in tightly grouped bands and bedded for several nights in the same location. These practices resulted in forage depletion and soil erosion from excessive trailing and trampling. Currently, areas with slopes in excess of 40 percent are considered nongrazable because of possible soil damage (fig. 9). Large thickets of upright willows are usually avoided, as are slopes below late-lying snowfields where bare soil would be exposed to trampling.

Under present management, sheep begin grazing most alpine allotments between July 10 and 15, and remain there for approximately 60 days. Bands usually consist of approximately 1,000 ewes with lambs under the direct supervision of a herder.

Forage utilization by domestic sheep is usually light. Recommended stocking rates for alpine ranges vary from 0.25 acre per sheep unit month on range in excellent condition to 5.5 acres on range in low-poor condition.

Figure 9.—Grazing and trailing by domestic sheep over steep slopes have caused excessive soil erosion. Abused areas are slow to recover because of the harsh environment.

Grazing Systems

Specialized grazing management, such as deferred or rotation systems, can be achieved by regulated herding. Planned movement of the band can achieve almost any pattern of grazing desired within constraints imposed by topography and access. Most current herding practices permit the sheep to graze while loosely bunched (open-herded) as the band moves slowly, but steadily, in a prescribed direction. Direction is determined by guiding the movement of the lead animals rather than herding the band from the rear. Most management plans stipulate the band will graze a given area only one time during the grazing season. One-night bedding on a well-drained site near where the band finishes grazing for the day is recommended. Salt is usually made available on the bedding ground.

"Herderless" management, where the animals are allowed to distribute themselves and graze according to their own wants, is sometimes practiced on alpine ranges. In these cases topographic features usually restrict movement of the animals beyond the allotment boundary; short sections of fence are sometimes required where terrain features do not confine their movement within the allotment. Claimed advantages are a wider distribution of animals over the range, elimination of concentration on bedgrounds, and a reduction of trailing damage. When unherded, the sheep have a tendency to graze the drier, rocky sites in preference to wet meadows, although the latter have greater forage production. Although better weight gains on lambs have also been reported, research in progress in northwestern Wyoming indicates no difference in lamb weights

between herded and nonherded bands. In this study the unherded bands usually moved as a single unit and tended to use the same areas for bedgrounds. The distributional behavior of these animals may be conditioned by past herding practices on the allotment, or to herding practices to which they are subjected during the rest of the year. The breed of sheep may also influence their tendency to band together.

Collection of unherded sheep at the end of the grazing period can be a problem if they are scattered widely. Sheepmen who follow this system find that the animals tend to drift to lower ranges with colder weather, where they can be gathered at concentration points.

Sheep losses due to predators may be high on alpine allotments. Some experienced sheepmen maintain, however, their losses are no higher with unherded bands than where the animals are under the supervision of a herder. In part, this can be attributed to the lack of competent sheepherders. Also, however, the dispersion of the band lessens the opportunity for a predator to inflict heavy losses on a band at one time.

Range Improvement Practices

Little information is available on the use of herbicides, fertilization, and seeding, or structural additions such as fences, water developments, and trails or roads on alpine ranges. Because forbs are important items in the sheep diet, the use of herbicides that remove forbs is not recommended unless few palatable forbs are present, and the elimination of nonforage species will stimulate growth of grasses and sedges. Under a deferred grazing system where certain areas are reserved for late-season use, forb control might be beneficial since sheep tend to use more grass and grasslike species at this time. In one reported study, the total standing crop was unchanged by herbicide treatment, although the grass:forb ratio was changed from 3:7 to 8:2.

Low levels of available nitrogen have been considered a factor limiting alpine plant growth, although small amounts of nitrogen fertilizer did not stimulate a rapid response. Other soil nutrients seem to be present in fairly adequate amounts.

Adequate stock water is usually not a problem on alpine ranges because of snow accumulation. Where sufficient water is not available to meet the needs of management, springs or seeps can usually be developed.

Since most bands are controlled by a herder, there has been little fence construction on alpine ranges. Where they have been built, initial and maintenance costs are often high, but because of the nature of the terrain only short sections usually are needed.

Roads and trails constructed for access are sources of considerable erosion. Scars persist for many years because of long years of use, poor design, and improper maintenance. Problems are especially serious where they have been built on windswept slopes and across wet snowbank areas and meadows. Skillful engineering design and continued maintenance are required to minimize erosion problems from such construction.

Attempts to revegetate these areas have usually been unsuccessful, but it has been accomplished on some local sites where exposure is not too severe. Seeding for range improvement and increased forage production is not common in the alpine.

Additional Needed Guidelines

The alpine ecosystem has many alternative uses. Management principles and practices determined in other ecosystems must be carefully considered before they are extrapolated to the alpine because of the harsh physical environment and the slow rate of recovery of plant cover and soil stability.

Existing range management principles for grazing of the alpine by domestic sheep are adequate. However, more precise criteria of range condition and trend are needed as a basis for multiple use management. Although certain standards developed for other ecosystems can be applied, the uniqueness of the alpine, including its dynamic environment, requires individual attention. A sound ecological classification of alpine sites is needed as a prerequisite to the development of improved standards.

Evaluation of the impacts of other activities and the value of other products of the fragile alpine ecosystem require careful additional study and monitoring. The system will deteriorate under the impacts of increased numbers of people who are attracted by its rugged beauty and wilderness attributes. Management guidelines for alleviating problem situations are scarce, and standards and criteria should be developed around a framework of sound ecological knowledge.

Other research is needed on the habitat requirements of the yearlong or transient wildlife of the alpine. Opportunities for providing additional habitat for the birds and animals, especially in the forest-alpine transition, have received minimal attention.

Activities that modify or manipulate the alpine snowpack, such as the erection of snowfences to increase the depth of natural snow and large-scale weather modification programs, need to be evaluated and the ecological changes that might ensue identified.

Additionally, controlled experimentation is needed on improvement of localized, deteriorated alpine sites.

RANGE RESOURCE PRIORITY PROBLEMS

Each of the foregoing resumes of existing knowledge for seven major range ecosystems of the central and southern Rocky Mountains concluded with a brief summary of land management problems that continue to exist after more than 70 years of range research and management efforts. Because of the complexity of the range environment, and because of rapidly changing demands upon and concerns for these ecosystems, the land manager today must often deal with new sets of problems that not long ago were entirely unfamiliar to him. For some areas, management has achieved success in empirically managing the resource; unfortunately, such knowledge is often unreported in the literature.

Continuing obstacles to sound, intensified multiple use have surfaced as a result of this review. Solution of the problems listed below will require additional research and management, but will have the benefit of rapidly evolving tools in ecosystem synthesis and analysis. The development of appropriate models that recognize the many interacting variables of the resource, coupled with sophisticated computer technology, can advance the decision capabilities of the resource manager.

The listing of "problems" that follows has been summarized from the individual ecosystem reports, which are the basis for this summary paper. Overall priorities for additional research by ecosystems were established by the author of this summary paper. The priorities are based upon (1) his overview of the needs and opportunities within the seven range ecosystems, and (2) consultations and technical reviews of the paper by knowledgeable research and management personnel.

- **Management prescriptions** for the range and related forest resources to coordinate the requirements of wildlife and human amenities in concert with domestic livestock use and other products. Available resource data provide general understanding of certain ecological relationships and range production capability. Where compatible data exist, they are useful in the development of models that help managers evaluate alternative ways of manipulating the resource. However, data for various wildlife, socioeconomic, or esthetic considerations are either lacking or inadequate.
  Ecosystem priority:
  1. Ponderosa pine-bunchgrass (central Rockies and Arizona).
  2. Semidesert grass-shrub.
  3. Mountain grassland.
  4. Chaparral.

- **Vegetation manipulation** to achieve optimum multiple use values from the range resource. Land managers have used prescribed fire, herbicides, fertilizers, mechanical devices, and biological agents to increase forage, water, or wood from the range and related forest ecosystems. Many areas have been seeded to exotic and native herbaceous and woody species to increase production or reduce erosion. Until recently, little attention had been given to the favorable or adverse impacts upon resource values other than conventional products. Opportunities exist for refinement of plant cover management to obtain greater productivity and harmony with all resource uses and values. We need to more specifically identify the proper time and techniques for application of existing and newly developed improvement measures.
  Ecosystem priority:
  1. Southwestern chaparral.
  2. Pinyon-juniper.
  3. Semidesert grass-shrub.

- **Indices and standards** of range resource potentials for better utilization, development, and management. More rapid, efficient, and accurate methods of classifying the ecosystem are needed to monitor change and forewarn the land manager of the need for corrective action. Such methods should provide a more detailed classification of the ecosystem and maps of the habitat units therein. Existing technology and data should be adapted and coordinated with new and improved equipment and technology as it becomes available.
  Ecosystem priority:
  1. Ponderosa pine-bunchgrass.
  2. Semidesert grass-shrub.
  3. Mountain grassland.
  4. Chaparral.
  5. Pinyon-juniper.
  6. Alpine.

- **Intensified ecological and physiological studies** of the range communities and components. Ecosystem synthesis and modeling advances can be employed for developing improved understanding of competitive and successional relationships, nutritional cycling, and energy flows. There are gaps in our knowledge, however, which will require additional field and laboratory research.
  Ecosystem priority:
  1. Pinyon-juniper.
  2. Mountain grassland.
  3. Southwestern chaparral.

- **Improved guidelines** for conventional range management practices. Rangelands produce a salable

product that can be marketed, if harvested by a grazing animal. To capitalize on this and contribute to the red meat supply, range management expertise should be expanded to incorporate innovative systems of grazing, techniques to improve animal distribution, dual or multiple use, and recognized range improvement measures integrated with native range utilization.

Ecosystem priority:

1. Mountain grassland.
2. Semidesert grass-shrub.
3. Southwestern chaparral.

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Summarizes a series of comprehensive reports on range management in the seven recognized ecosystems: Semidesert grass-shrub, southwestern chaparral, pinyon-juniper, central Rockies ponderosa pine-bunchgrass, Arizona ponderosa pine-bunchgrass, mountain grassland, and alpine. Includes what is known, what can be recommended, and what additional information is needed for each ecosystem.

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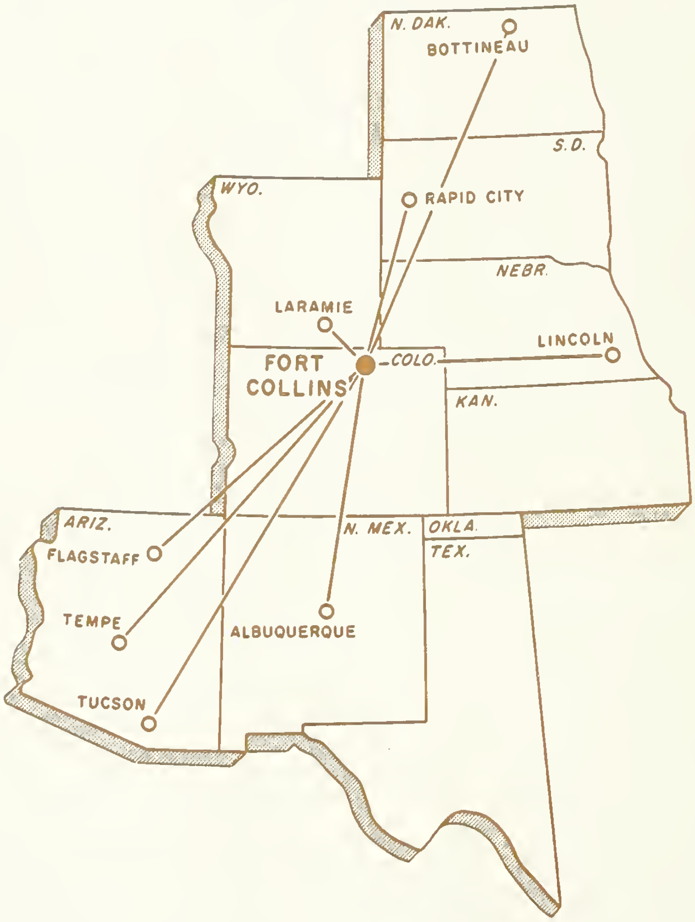

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